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**HIGH ENERGY PHYSICS DIVISION
SEMIANNUAL REPORT OF
RESEARCH ACTIVITIES**

January 1, 2000 - June 30, 2000

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Abstract

This report describes the research conducted in the High Energy Physics Division of Argonne National Laboratory during the period of January 1, 2000 through June 30, 2000. Topics covered here include experimental and theoretical particle physics, advanced accelerator physics, detector development, and experimental facilities research. Lists of Division publications and colloquia are included.

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I. EXPERIMENTAL RESEARCH PROGRAM

IA. EXPERIMENTS WITH DATA

IA.1 Medium Energy Physics Program

There was a considerable change in emphasis for the ANL-HEP division medium energy physics project during the first half of 2000. A request to DOE for additional funding to work on the STAR detector endcap electromagnetic calorimeter (EEMC) construction, spin measurements with STAR at RHIC, and polarimetry for RHIC, was approved early in this period. Work was begun on the EEMC design and construction. In addition, analysis of recent data from the Crystal Ball detector at the Brookhaven AGS continued. Also, a paper on Saclay measurements of pp elastic-scattering spin observables was essentially finished, and another is nearing completion.

An ANL physicist is writing two long papers about measurements of pp elastic-scattering spin observable data obtained with a transversely polarized beam and polarized target. The kinetic energies of the beam range from 800 to 2800 MeV and the c.m. angles are typically 70° to 110°. The results are based on data analysis performed at Saclay and Argonne. One paper awaits final corrections from the authors and will be submitted early in the next period. The other exists as a nearly complete draft, and it is hoped to have it also submitted during the next few months. The results at 70°, 80°, and 90° exhibit no sharp energy dependence in the energy range covered.

Measurements of reactions with p^- , K^- , and antiproton beams on a liquid hydrogen target to all neutral final states were made with the Crystal Ball detector at the Brookhaven AGS. Analysis of some of the kaon data has continued at Argonne and Valparaiso University. In addition, a paper was published ("Search for the CP-Forbidden decay $h \rightarrow 4p^0$ ") by S. Prakhov et al., Phys. Rev. Lett. **84**, 4802 (2000)), and another was submitted ("Measurement of $p^0 p^0$ Production in Nuclear Matter by p^- at 0.408 GeV/c" by A.B. Starostin et al.) to Phys. Rev. Lett. An instrumentation article describing the neutron detection efficiency in the NaI detectors of the Crystal Ball, using pp charge exchange data, is being written at Valparaiso and is nearly ready for submission.

A proposal for additional kaon running using the same apparatus and four of the eight beam momenta used previously was presented to the Brookhaven Program Advisory Committee. An Argonne physicist is one of the co-spokesmen of this proposal. A special panel of experts on baryon spectroscopy also evaluated this proposal. Approval was granted for 450 additional hours of beam time to run this experiment, probably in the fall of 2001. The physics will focus on several special Λ^* and Σ^* resonant states, some of which are not expected in conventional quark models of baryons.

The proposed program at RHIC and STAR was presented to DOE on January 31, 2000, and a funding increase for this work was approved. One component of this research will be the construction of a shower maximum detector (SMD) for the STAR EEMC. Small triangular strips of plastic scintillator, with wavelength shifter (WLS) fiber readout to multianode photomultipliers, will be used for the SMD construction. The SMD modules are approximately 30° sectors with an inner radius about 75 cm and an outer radius of 215 cm. The strips will run at 45° to the bisector of the 30° module, and the readout fibers will be routed to the outer radius. The second component of this research will involve spin physics measurements with STAR using polarized beams of protons. The goals will be the determination of the gluon contribution to the proton spin via the process $p + p \rightarrow g + \text{Jet} + X$ ($q g \rightarrow g q$), and the flavor separation of the sea-quark spin distributions via W production. The EEMC and SMD are particularly important for these measurements. The third component will involve participation in various aspects of RHIC and AGS polarimetry. ANL equipment is used extensively in the AGS polarimeter, and Argonne physicists have considerable expertise in measuring the beam polarization at various accelerators.

The construction of the EEMC is in collaboration with a number of university groups within the STAR collaboration. The EEMC project is led by a group at the Indiana University Cyclotron Facility, and funded by NSF. Some of the materials for the SMD will be supplied by this grant and by collaborating institutions. The SMD construction and cosmic ray testing will occur at Argonne. The added DOE funding for ANL-HEP scientists will permit hiring of two new postdoctoral fellows for work on the medium energy physics project.

Approximately 320 triangular polystyrene strips (non-scintillating) were extruded late last year, each with a length about 3.0 m. The dimensions were roughly 5 mm high with a base of 10 mm, with a 1-mm hole for the WLS fiber in the center. The distribution of heights and widths for about half of these strips is shown in Figure 1. The dimensions are slightly less than the nominal because of rounded corners on the triangular cross section during the extrusion process. The strip to strip variation is seen to be less than $\pm 1\%$. In the original SMD design, scintillator strips of these dimensions were to be wrapped in aluminized mylar, and then glued into a single module. A polystyrene sheet of 1.5 mm would serve both as a structural material and also as space to route the fibers to the outer radius of the modules.

About 240 of these triangular strips were wrapped in aluminized mylar. This was done with a modified magnet-winding machine at IUCF. The mylar was cut from a large roll of much wider material. About 230 of the strips were done in one period, with various adjustments to try to achieve a smooth and uniform wrapping. Based on this work, it was estimated that one person could wrap the strips for a single module in about three days. A slightly different wrapping scheme was used, with improved results, for ten more strips later in this period. Some suggested improvements in the wrapping machine were noted, and these were discussed with an IUCF engineer.

A number of test gluings of the strips were made. These were to gain experience with all aspects of assembling the module before machining to final dimensions. The accuracy of placement of the strips was tested with a travelling microscope by inserting fibers in the extruded holes and viewing the fibers. Instead of a jig, threaded rods were used to place the strips. The epoxy previously used by members of the Fermilab D0 detector collaboration at Brookhaven and Stony Brook was tried for these gluings. Several gluings of about 40 short strips each were made, some with wrapped and others with unwrapped strips. It was found that the strips could be located to about $\pm 0.1 - 0.2$ mm with the threaded rods. One gluing with about 60 strips of length 1 m was also performed, and this demonstrated problems handling a large number of strips.

Based on experience with the gluings, it was concluded that a good jig would be required for the final module assembly. People at both Argonne and IUCF considered several jig designs, and a prototype jig was agreed upon in late March. Detailed drawings were generated at IUCF, and the jig is presently under construction. It will be used to make a full-size mechanical prototype SMD module using the present strips to evaluate its effectiveness. After gluing the strips into a module, the assembly will be machined to final dimensions at IUCF, before installing the readout fibers.

After a design review of the EEMC in February, it was decided to increase the triangular strip height from 5 mm to 7 mm in order to increase the light yield. Measurements from the gluings assisted in this decision. Another gluing will be made soon to confirm the module thickness estimate from the previous gluings.

A pair of 64-channel Hamamatsu multianode photomultiplier tubes, several plastic scintillator strips from the Fermilab D0 detector, and WLS fibers were borrowed from IUCF, and tests were begun with these at Argonne. The response of one of the strip – WLS fiber – photomultiplier combinations was mapped across the strip with a momentum analyzed “beam” of electrons from a ^{106}Ru source. In addition, the gain of a 16-channel tube borrowed from MINOS was compared to that of one of the 64-channel tubes and found to be considerably higher. Such studies are continuing in order to develop schemes for checking the SMD modules during assembly for quality control purposes.

A cosmic ray test facility was designed and construction begun. The purpose of the facility will be to map the response of the SMD modules once they are constructed. This mapping will be done strip by strip, as a function of position along the strips; an exponential decrease with decay distance of a few meters is expected. A set of 14 existing plastic scintillation counters with photomultipliers on each end were tested and prepared for mounting. They will be divided into two sets of seven, and used as trigger counters above and below the other components in the facility. Two large multiwire proportional chambers with active areas 0.76 m x 1.02 m were brought from storage and tested. Each has four sense wire planes (X, Y,

U, V) with 2 mm wire spacing. Unfortunately, these chambers were found to have broken wires that will require repair. The unistrut support for the chambers and scintillation counters was started.

In addition to these preparations, a large ADC system previously used at the Fermilab CDF detector was obtained. Work was begun to set up and test this system for use in reading out the SMD multianode photomultipliers for the cosmic ray test facility. Two new power supplies were purchased to supplement existing low voltage supplies.

Arrangements were made for a major extrusion of scintillator strips for the SMD modules. Assistance was received from two scientists at Fermilab who had worked on the D0 and MINOS extrusions. It was decided to use the well-studied D0 scintillator formula. Polystyrene pellets, scintillation dopants, and other materials were ordered. These will be mixed and reformed into pellets at a “compounding” company, and then moved and extruded at a separate firm. The die design for the extrusion was specified and it is being manufactured. These two companies have experience with the production of plastic scintillator extrusions, having worked with the D0 and MINOS groups. It is anticipated that the extrusion will occur in a few months.

(H. M. Spinka)

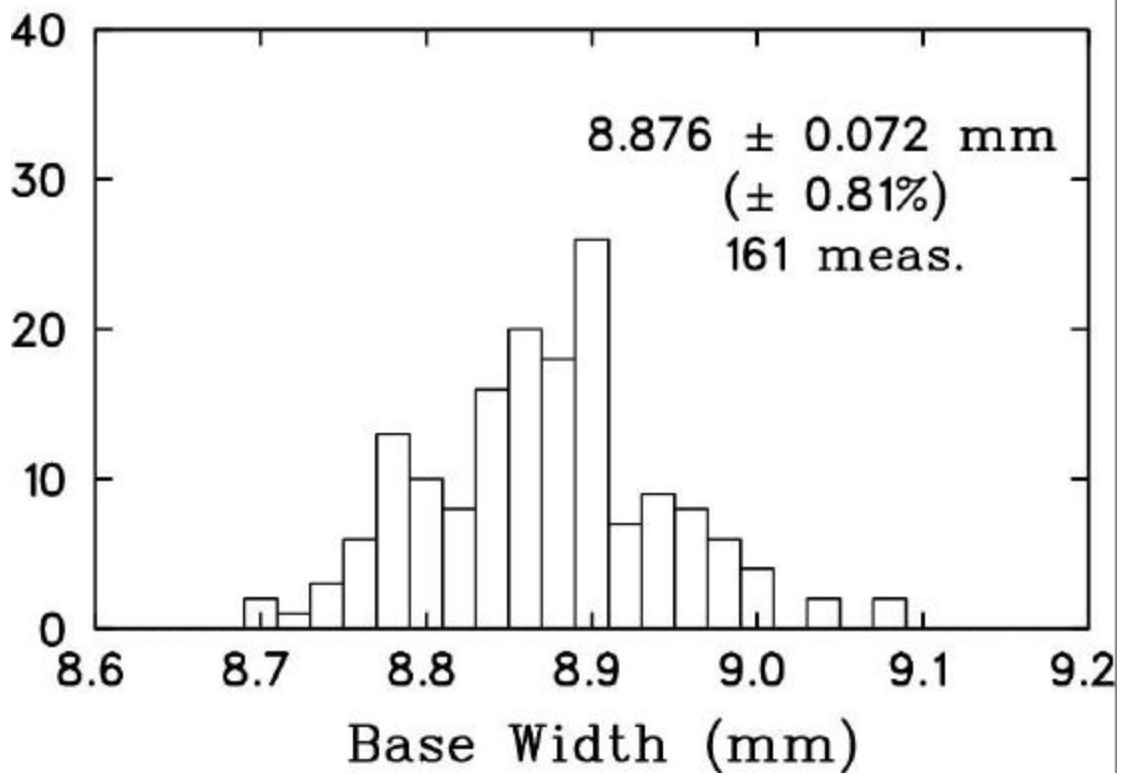
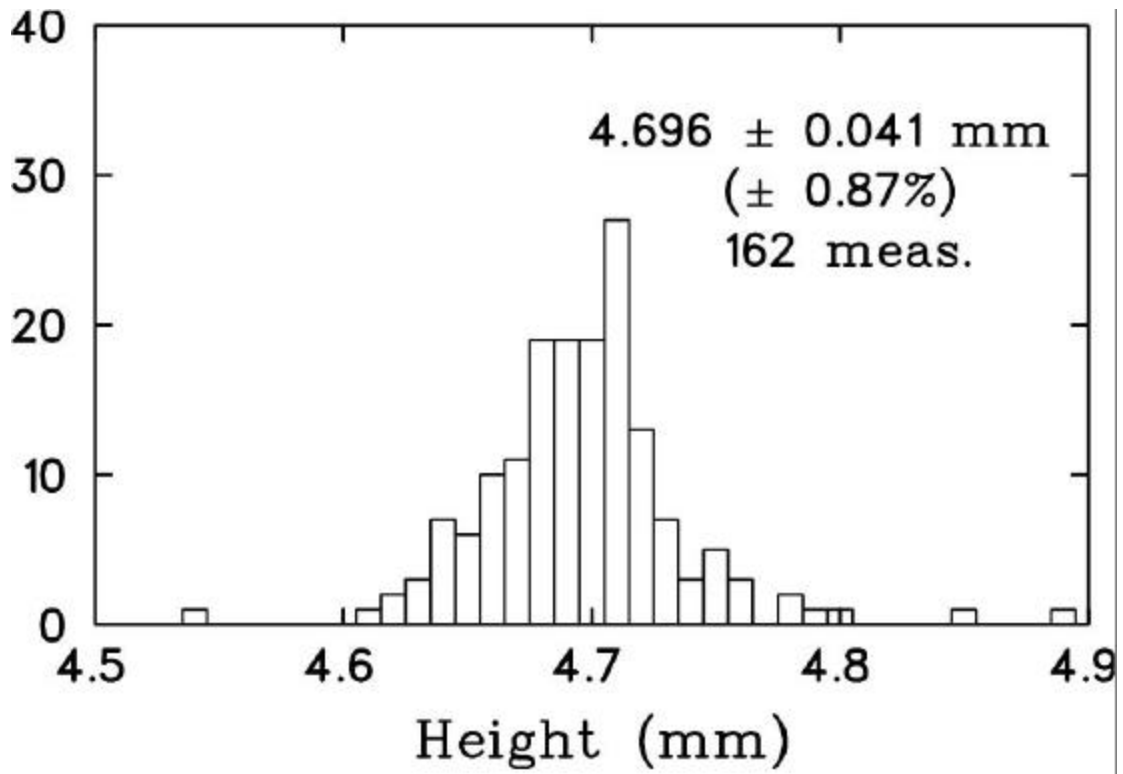


Figure 1. Measurements of dimensions of the extruded triangular strips for the STAR endcap electromagnetic calorimeter.

I.A.2 Collider Detector at Fermilab

a. Physics Results

In B physics, the multiple tag CP analysis of $B^0 / \bar{B}^0 \rightarrow \mathbf{y} K_s^0$, with Barry Wicklund providing oversight as B physics convener and Larry Nodulman appointed as chief internal reviewer, which measures the CP violation parameter $\sin(2\mathbf{b}) = 0.79^{+0.41}_{-0.44}$, was published in the Physical Review and we await results from the b factories to eventually overwhelm this measurement. Barry Wicklund continues as B physics co-convener, concentrating on developing trigger and dataset strategies as well as cleaning out remaining Run 1 physics.

In electroweak physics, the W mass analysis was written up in a long article submitted to Physical Review, with Larry Nodulman contributing text and helping with required edits. The electron and muon result for the 94-95 data is 80.470 ± 0.089 , which combined with earlier CDF measurements gives $80.433 \pm 0.079 \text{ GeV}/c^2$. The current world average is $80.419 \pm 0.038 \text{ GeV}/c^2$. Adam Hardman's work on the W width from the muon sample, combined with the electron result has been published, $\Gamma_W = 2.04 \pm 0.11 (stat) \pm 0.09 (sys) \text{ GeV}$, the best direct measurement.

In QCD studies, Steve Kuhlmann, working with the Brandeis group, is continuing the study of direct photon production in the 94-95 data in both the $\sqrt{s} = 630 \text{ GeV}$ and 1800 GeV data, and in association with muons. Jet algorithm optimization studies, aimed at Higgs searches, are continuing as illustrated in Figure 1. Bob Blair continues as co-convener of QCD physics.

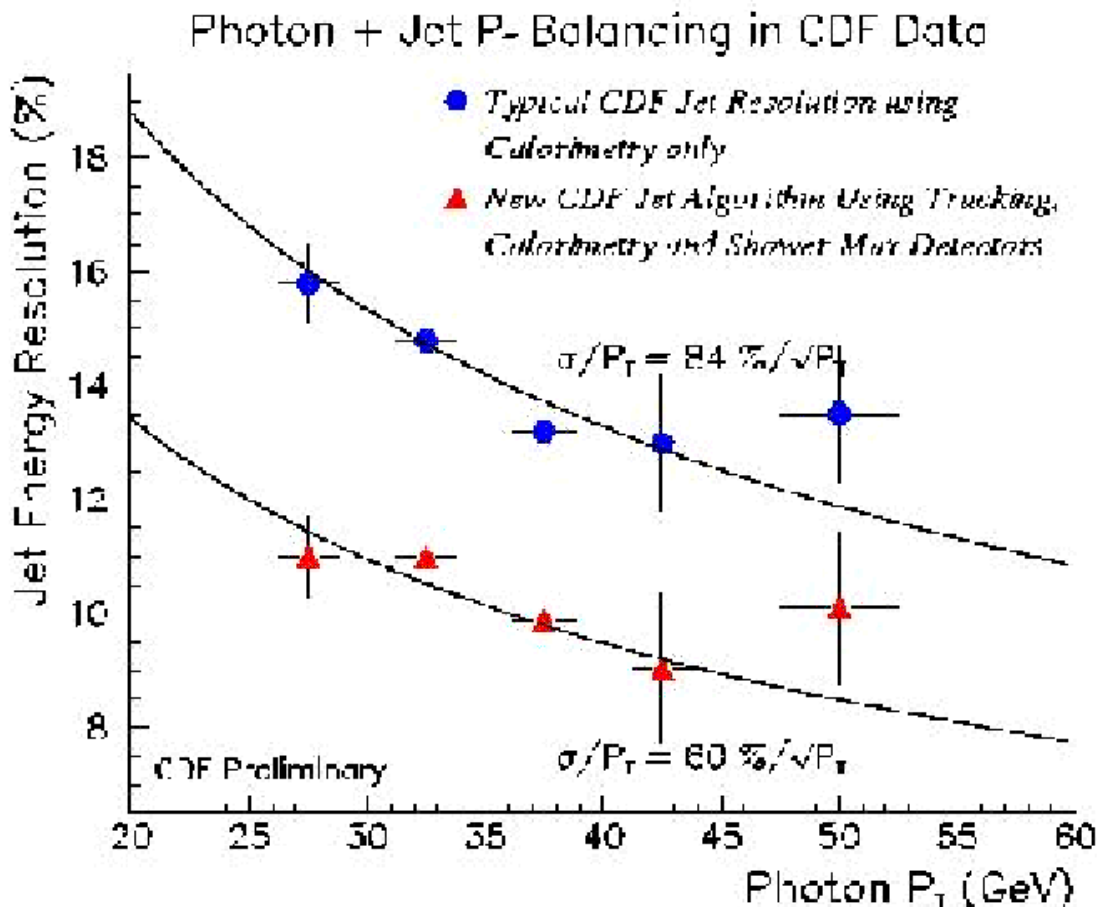


Figure 1. Latest status of the improved Dijet mass measurement. The Dijet mass algorithm sets noise standards for central shower max strip readout.

b) Run II Planning

A series of Run II physics workshops continues at Fermilab. Steve Kuhlmann has taken a leading role in QCD issues as well as optimizing two b jet mass resolution for Higgs searches. Larry Nodulman has been involved in electroweak sessions, on W production issues. A workshop on Tevatron Collider b physics for CDF, DØ and BTeV was organized with Barry Wicklund as one of the principal organizers. Karen Byrum and Will Bell contributed projections of possible CDF results from Run II on extending the transverse momentum reach for b production measurement, illustrated in Figure 2 and searching for $B_s \rightarrow \gamma h'$. Extending the b cross section to higher p_T sharpens the confrontation with QCD. The $\gamma h'$ decay mode may be of CP interest.

(L. J. Nodulman)

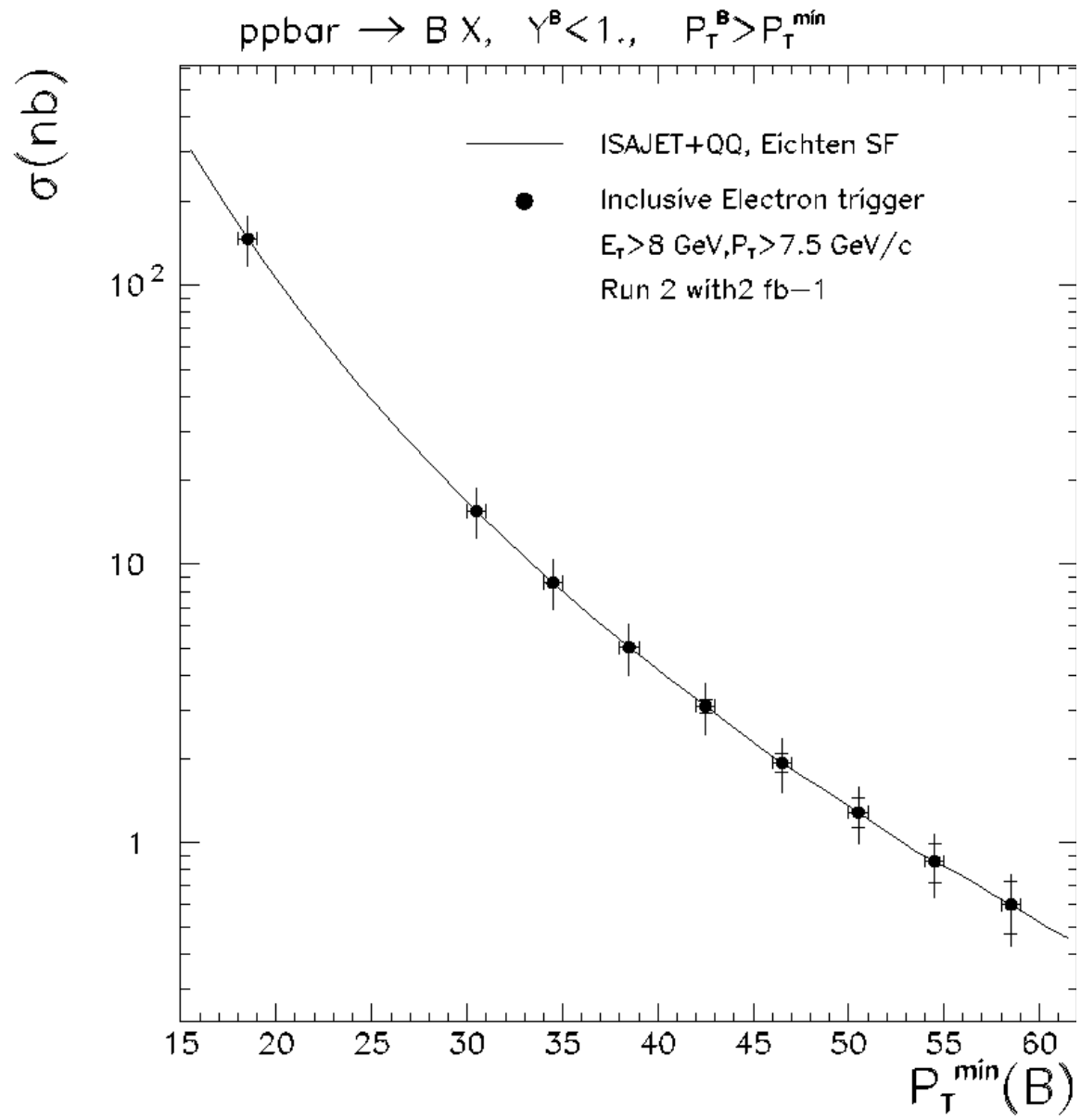


Figure 2. Expected precision for b production extending to higher p_T in Run II.

I.A.3 Non-Accelerator Physics at Soudan

a. Physics Results

The Soudan-2 detector continues to operate and analysis of contained events and muons continues to shed new light on the atmospheric neutrino anomaly and the search for nucleon decay. Other continuing analyses involve seasonal variations, magnetic monopoles, neutrinos from active galactic nuclei, and variations through the solar cycle of the “sun shadow”.

The future operation of the Soudan 2 detector depends on whether or not the MINOS collaboration feels it provides additional strengths in the context of a long-baseline neutrino oscillation experiment to justify its continued operation. A working group has been studying THESEUS refers to continued running of the Soudan 2 tracking calorimeter as a component of the MINOS long-baseline neutrino oscillation experiment. The THESEUS Working Group was set up to examine this proposal.

The conclusions of the Working Group are:

1. The high resolution of THESEUS provides complementary capabilities for several physics topics where THESEUS can add significantly to the MINOS results despite its lower mass, for example:
 - the identification of minor $\nu_\mu \rightarrow \nu_e$ oscillation components with determination of or limit setting for U_{e3}^2 ,
 - the measurement of Δm^2 and $\sin^2(2q)$ in the ν_μ charged current interaction at low neutrino energies,
 - the identification of $\nu_\mu \rightarrow \nu_\tau$ oscillations via the $\tau \rightarrow \rho$ decay, if Δm^2 is large.

The common feature of these processes is that good pattern recognition is required to separate signal from background.

2. Although some physics could be done by the existing THESEUS detector as currently operating at Soudan, the physics to which THESEUS makes the greatest contribution requires the deployment of a small near detector, configured using existing calorimeter modules extracted from the far detector. This would enable a significant reduction of systematic errors by measuring the backgrounds to the above rare processes, rather than relying on Monte Carlo simulations of the background.

3. The Working Group recommends that the THESEUS far detector be incorporated into the MINOS experiment and that it be maintained and operated to ensure that it is ready to run at first beam. The group also recommends that a THESEUS near detector be assembled at a cost of approximately \$1.2M, with a schedule which allows installation after the completion of the MINOS near detector (2004).

With its fine granularity, THESEUS is well positioned to measure $\bar{\nu}_m \rightarrow \bar{\nu}_e$ events. The main problem is the separation of true charged current events from neutral current \bar{p}^0 production. This is done both in MINOS and THESEUS by examining the shape of the shower. However, the fine granularity of THESEUS provides superior separation using the two main distinguishing characteristics:

1. Showers initiated by \bar{p}^0 decays are generally broader than prompt electron showers because of the presence of two γ 's having angular separation.
2. There is a typical radiation length (12 cm) gap between the production vertex and the shower conversion point.

Separation of $\bar{\nu}_e$ from NC and from other backgrounds had been considered in two independent analyses of low energy beam data summarized in more detail in our companion document and fully described in reference. The two analyses use different amounts of scanning information. One is almost independent of scanning. The other, which achieves a better limit, uses a final scan to reject further background events.

The detection efficiency for electron charged current events in THESEUS and MINOS is shown in Figure 1. The points with error bars are the THESEUS efficiencies, the histogram those of MINOS. It can be seen that at neutrino energies above 5 GeV the efficiencies are roughly equal but at low energies THESEUS is superior with efficiencies remaining at between 50 and 60% to below 2 GeV.

The analysis uses broadly similar techniques, using cuts on similar quantities, and the same beam spectrum as the THESEUS analysis. Currently new analyses are in progress which use more sophisticated selection techniques, including neural networks, and include the effects of the hadronic hose, beam plug and matter effects in the Earth. These give limits up to a factor of two better than the old MINOS analysis. These improvements can in future be incorporated into the THESEUS analysis and might be expected to give similar improvements in limits. For the present we believe that comparison of the two analyses described here gives a realistic comparison of the sensitivities of the two detectors.

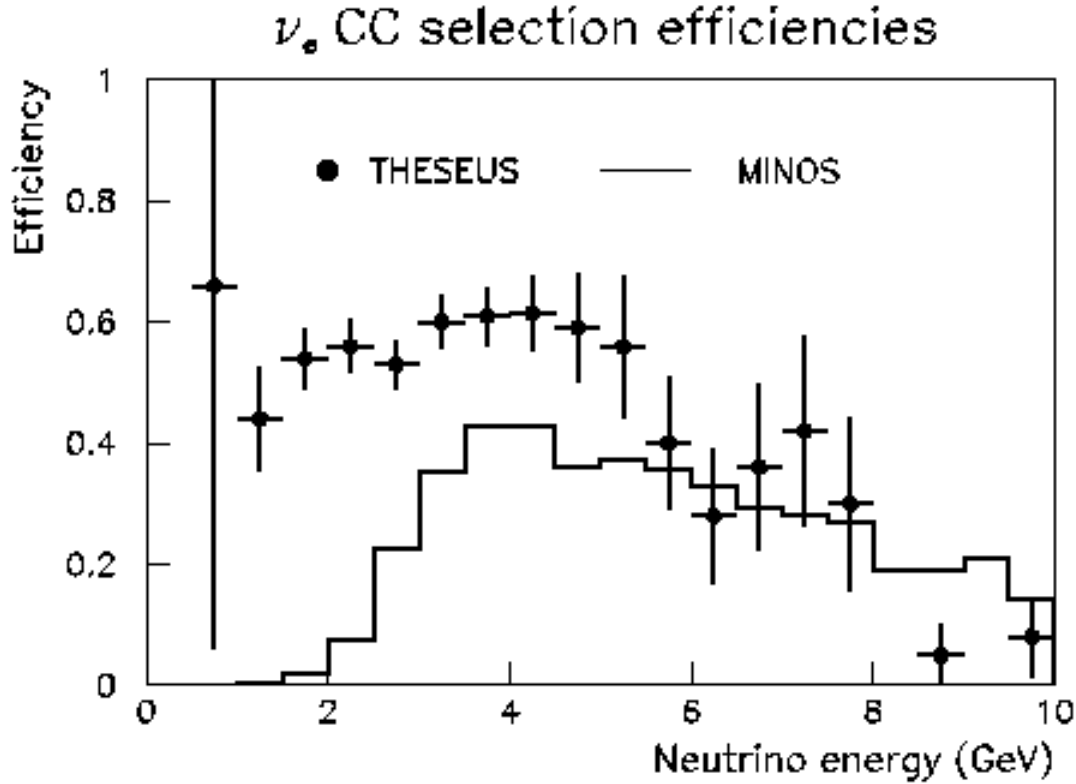


Figure 1. Selection efficiency of ν_e charged current events as a function of neutrino energy for THESEUS (points with error bars) and MINOS (solid histogram).

This systematic error can largely be removed by the addition of a near THESEUS detector. A precise measurement of the background would be obtained at the near detector. Only the extrapolation of the beam spectrum to the far detector would introduce systematics. However, since event topology is a relatively weak function of beam energy, the effects of the uncertainties expected in the beam extrapolation would be small compared with the statistical precision of the data.

At a Δm^2 of $3.5 \times 10^{-3} \text{eV}^2$, the first oscillation maximum occurs at a neutrino energy of approximately 2~GeV, matched to the low energy beam spectrum and to the region in which THESEUS has its best energy resolution and muon containment. At these neutrino energies the muon from charged current interactions often has an energy where its range is comparable to that of the hadron shower. The fine granularity and pictorial capabilities of the THESEUS detector enables muons to be separated from the hadron shower at lower muon energies than is possible in MINOS, thus improving the separation of charged current from neutral current interactions.

A standard Soudan 2 analysis has been carried out to scan and reconstruct a Monte Carlo two-year sample of low energy beam events. 770 measurable events were identified, 266 were completely contained (CEV), 504 were partially contained (PCE). The final state muon track was identified in 575 events. Table 1 shows the number of expected identified $n_{\mu\text{CC}}$ events for various oscillation hypotheses and data-taking periods, together with the potential number of S of an observed effect. It can be seen that for an initial 3 month equivalent run a $3S$ or greater effect would be observed for Δm^2 larger than $\sim 0.003 \text{eV}^2$.

	No Oscillations	$\Delta m^2 = 0.002$		$\Delta m^2 = 0.003$		$\Delta m^2 = 0.005$	
Period	Number	Number	S	Number	S	Number	S
2 Years	575	457	5.2	366	8.8	279	12.4
6 Months	144	114	2.6	91	4.4	70	6.2
3 Months	72	57	1.8	46	3.1	35	4.4

Table 1. Number of identified $n_{\mu\text{CC}}$ events for various Δm^2 with $\sin^2(2q)=1.0$ and for 2 year, 6 month, and 3 month runs. The number of S of the observed depletion, assuming perfect understanding of the beam, is also given.

The contained events were completely reconstructed and the total visible energy determined from the range of tracks and the number of hits in showers. The partially contained events had a lower limit to the total energy given by the range of the muon in the detector. Figure 2 shows the CC selection efficiency as a function of neutrino energy for both THESEUS and MINOS. The THESEUS selection efficiency is about 10% higher than that of MINOS.

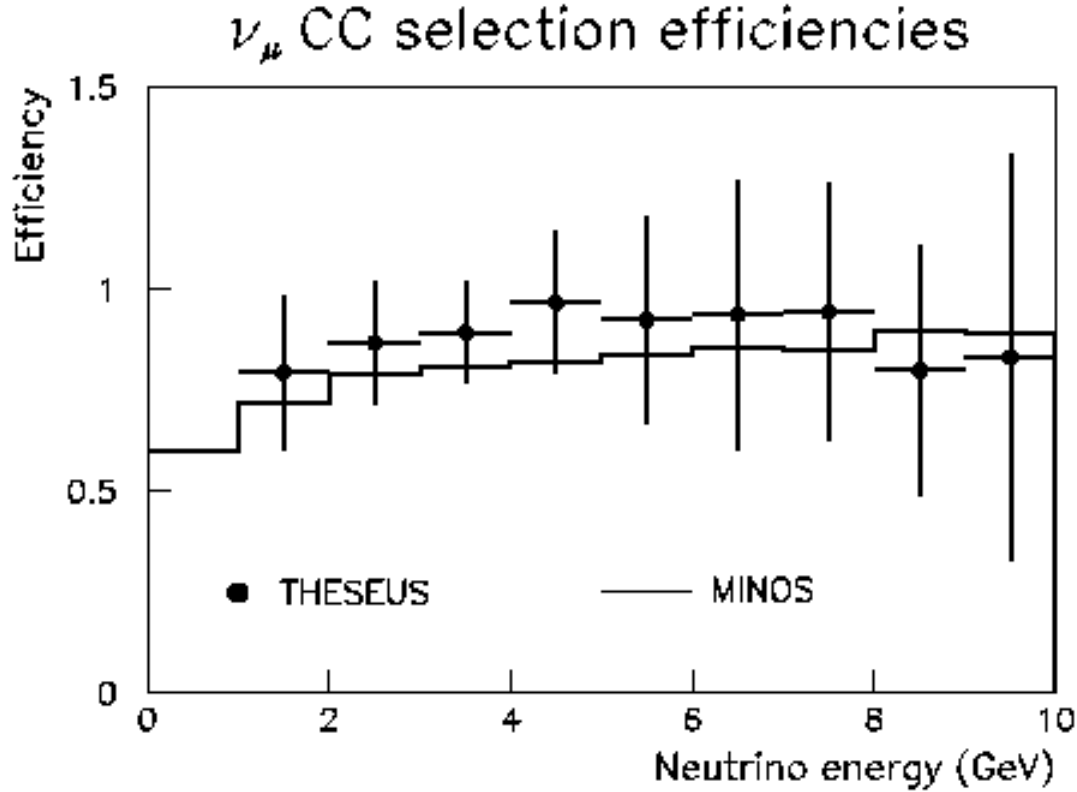


Figure 2. The selection efficiency in THESEUS as a function of neutrino energy (points with errors) and in MINOS (solid histogram).

With a cut requiring a contained, identified muon to be longer than 150 cms, a total of 100 contained events was obtained. Of these 93 were true ν_μ charged current events. Figure 3 shows the oscillated and unoscillated reconstructed neutrino energy distribution for a Δm^2 of 0.0003 eV^2 and $\sin^2(2\theta)$ of 0.8, for the CEV and PCE samples and for the combined sample. Also shown are the 68% and 90% error contours for the three cases. For the combined sample the contours are determined by adding the χ^2 for the individual samples. The oscillation depletion is clearly visible. The poor statistics at low energies where it would be instructive to see the rise below the oscillation maximum is due mostly to a lack of beam neutrinos. THESEUS still has a good detection efficiency in this region.

Theseus, Ph2le, 2 kt. yr. $\Delta m^2=0.003$, $\sin^2 2\theta=0.8$

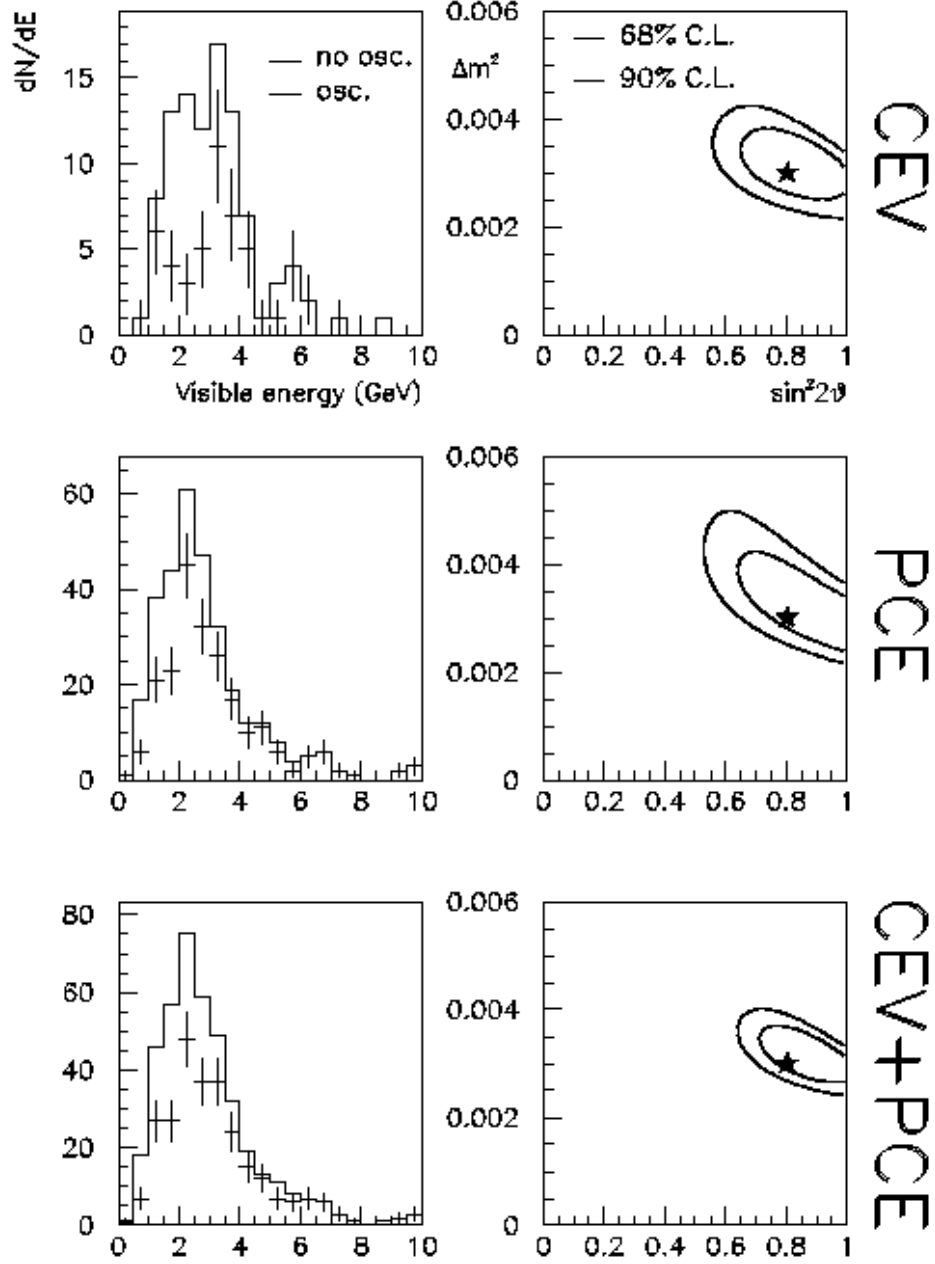


Figure 3. Top plots. Left: Distribution of reconstructed neutrino energy expected for a two-year run of the low-energy NuMI beam for $\nu_\mu \rightarrow \nu_\tau$ oscillations with $\Delta m^2 = 0.003 \text{ eV}^2$ and $\sin^2(2\theta) = 0.8$ for fully contained events. Right: Error contours from a fit to the distribution. Center plots: Same for the partially contained sample. Bottom plots: Same for the combined sample.

Together the $\nu_m \rightarrow \nu_e$ and ν_m charged current analyses in THESEUS will provide valuable independent confirmation for the main results of the MINOS project.

The THESEUS $\nu_m \rightarrow \nu_e$ analysis can approximately double the overall power of MINOS for this crucial analysis. The region of THESEUS/MINOS sensitivity not ruled out at 90% confidence by CHOOZ is limited. However, it is important for knowledge of the MNS matrix to push these measurements as far as possible, particularly as the program for future neutrino factories is largely based on measurements of these off-diagonal elements of the matrix. Plans for neutrino factories are being made on the assumption that θ_{13} (or U_{e3}) is non-zero. If, and only if, this is the case is there the possibility of observing CP-violation with a neutrino factory. It is therefore imperative that current long-baseline experiments achieve the maximum sensitivity to $\nu_m \rightarrow \nu_e$ oscillations in order to test the validity of this assumption and provide input to the design of neutrino factories.

The charged current analysis gives larger error contours than MINOS alone, but the extra NC/CC separation power at low muon energies provides important systematic checks on the method as well as adding some statistical power in the middle range of the Super-Kamiokande allowed region. The THESEUS detector will be available, with a fully debugged analysis system, at day one of beam operations. Within a relatively short period, it will provide preliminary data on the beam intensity and oscillation effects, possibly while the MINOS detector and analysis system are being commissioned on real data.

b. Experimental Apparatus, Operation and Maintenance

Argonne physicists continued to make substantial contributions to the maintenance and operation of the detector. Major activities included ongoing improvements of detector and electronics performance. Argonne physicists also continued the development of software to make use of dE/dx information from the detector.

c. Planning Activities

The Soudan group plans to run the detector for nucleon decay, atmospheric neutrino, and other cosmic ray studies until an exposure of 5.0 kt-year fiducial volume is achieved. After that, the Soudan detector will become an integral part of the MINOS long-baseline neutrino oscillation experiment. The progress on that project is described elsewhere in this report.

(M. C. Goodman)

I.A.4 ZEUS Detector at HERA

a. Physics Results

Thirteen papers were published in this period and two more manuscripts were submitted for publication. In the following, we shall summarize some of the papers published in this period of time.

i) *Measurement of High Q^2 Charged Current e^+p Deep Inelastic Scattering Cross Sections at HERA*

The e^+p charged-current deep inelastic cross sections, $d\mathbf{s}/dQ^2$ for Q^2 between 200 and 60000 GeV^2 and $d\mathbf{s}/dx$ and for $d\mathbf{s}/dy$ for $Q^2 > 200 \text{ GeV}^2$, have been measured using a data sample of 47.7 pb^{-1} . The cross section $d\mathbf{s}/dQ^2$ falls by a factor of about 50000 as Q^2 increases from 280 to 30000 GeV^2 . The double differential cross section $d^2\mathbf{s}/dx dQ^2$ has also been measured, see Figure 1.

A comparison between data and Standard Model predictions shows that contributions from both antiquarks (\bar{u} and \bar{c}) and quarks (d and s) are required by the data. The predictions give a good description of the full body of the data. A comparison of the charged-current cross sections $d\mathbf{s}/dQ^2$ with recent ZEUS results for neutral-current scattering shows that the weak and electromagnetic forces have similar strengths for Q^2 above M_W^2, M_Z^2 . A fit to the data for $d\mathbf{s}/dQ^2$ with the Fermi constant G_F and M_W as free parameters yields $G_F = (1.171 \pm 0.034 \text{ (stat.)}^{+0.026}_{-0.032} \text{ (syst.)}^{+0.016}_{-0.015} \text{ (PDF)}) \times 10^{-5} \text{ GeV}^{-2}$ and $M_W = 80.8^{+4.9}_{-4.3} \text{ (stat.)}^{+5.0}_{-4.0} \text{ (syst.)}^{+1.4}_{-1.3} \text{ (PDF)} \text{ GeV}$.

ii) *Measurement of $D^{*\pm}$ Production and the Charm Contribution to F_2 in Deep Inelastic Scattering at HERA*

The production of $D^{*\pm}$ (2100) mesons in deep inelastic scattering has been measured using an integrated luminosity of 37 pb^{-1} . The e^+p cross section for inclusive $D^{*\pm}$ production with $1 < Q^2 < 600 \text{ GeV}^2$ and $0.02 < y < 0.7$ is $8.31 \pm 0.31 \text{ (stat.)}^{+0.30}_{-0.50} \text{ (syst.) nb}$ in the kinematic region $1.5 < p_T(D^{*\pm}) < 1.5$ and $|\mathbf{h}(D^{*\pm})| < 1.5$. Differential cross sections are consistent with a next-to-leading order perturbative QCD calculation when using charm fragmentation models, which take into account the interaction of the charm quark with the proton remnant. The observed cross section is extrapolated to the full kinematic region in $p_T(D^{*\pm})$ and $\mathbf{h}(D^{*\pm})$ in order to determine the charm contribution, $F_2^{c\bar{c}}(x, Q^2)$, to the proton structure function. The ratio $F_2^{c\bar{c}}/F_2$ is shown in Figure 2 and rises from about 10% at $Q^2 \cong 1.8 \text{ GeV}^2$ to $\cong 30\%$ at $Q^2 \cong 130 \text{ GeV}^2$ for x values in the range 10^{-4} to 10^{-3} .

ZEUS CC 1994-97

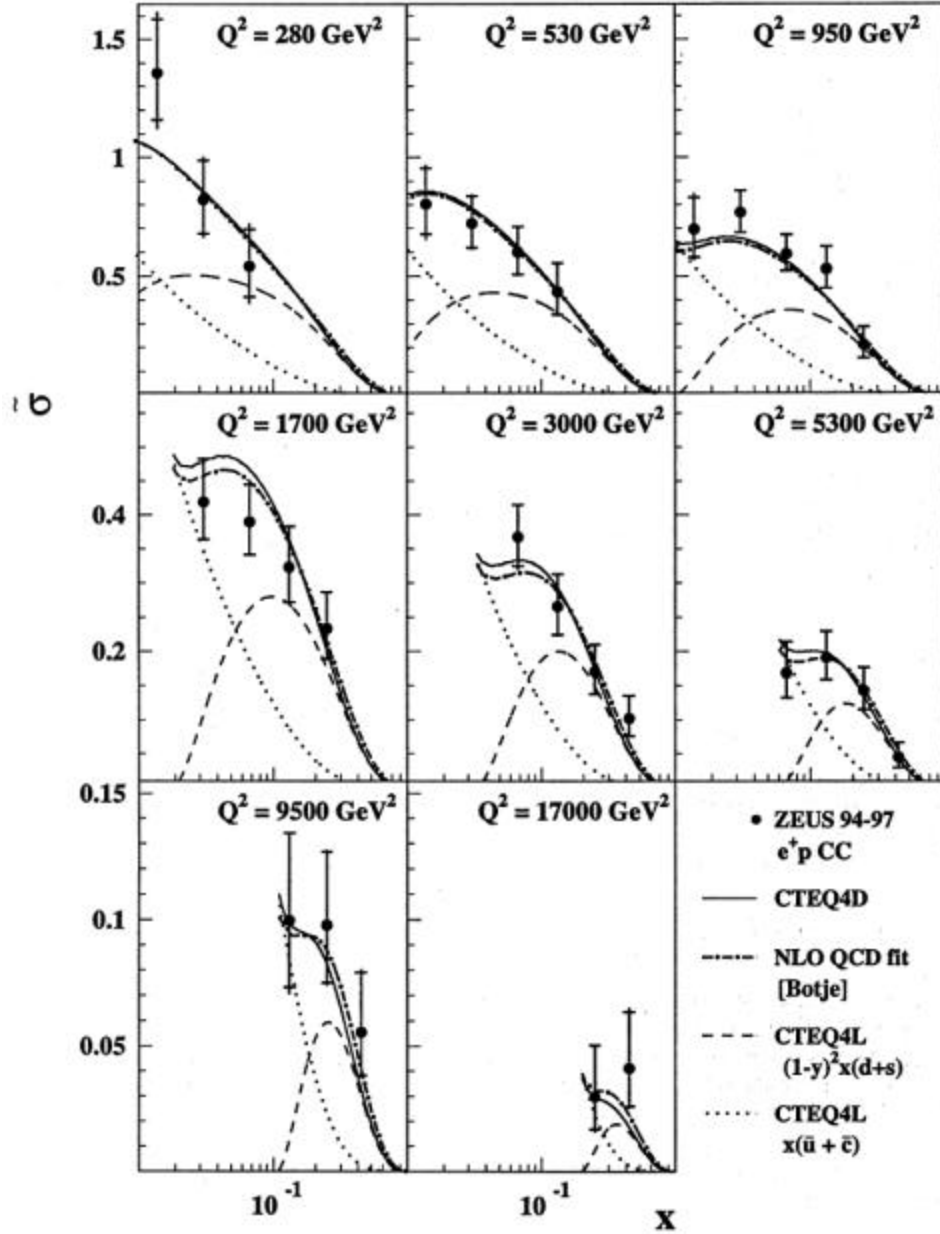


Figure 1. The reduced charged-current cross section $\tilde{\sigma}$ as a function of x , for fixed values of Q^2 . The dots represent the data, while the expectations of the Standard Model evaluated using the CTEQ4D PDFs are shown as the solid lines. For illustration, the leading-order PDF combinations $x(\bar{u} + \bar{c})$ and $(1-y)^2 x(d+s)$, taken from the CTEQ4L parameterization, are also plotted as dotted and dashed lines, respectively. Also shown is the result of the NLO QCD fit by M. Botje (dash-dotted line).

ZEUS 1996–97

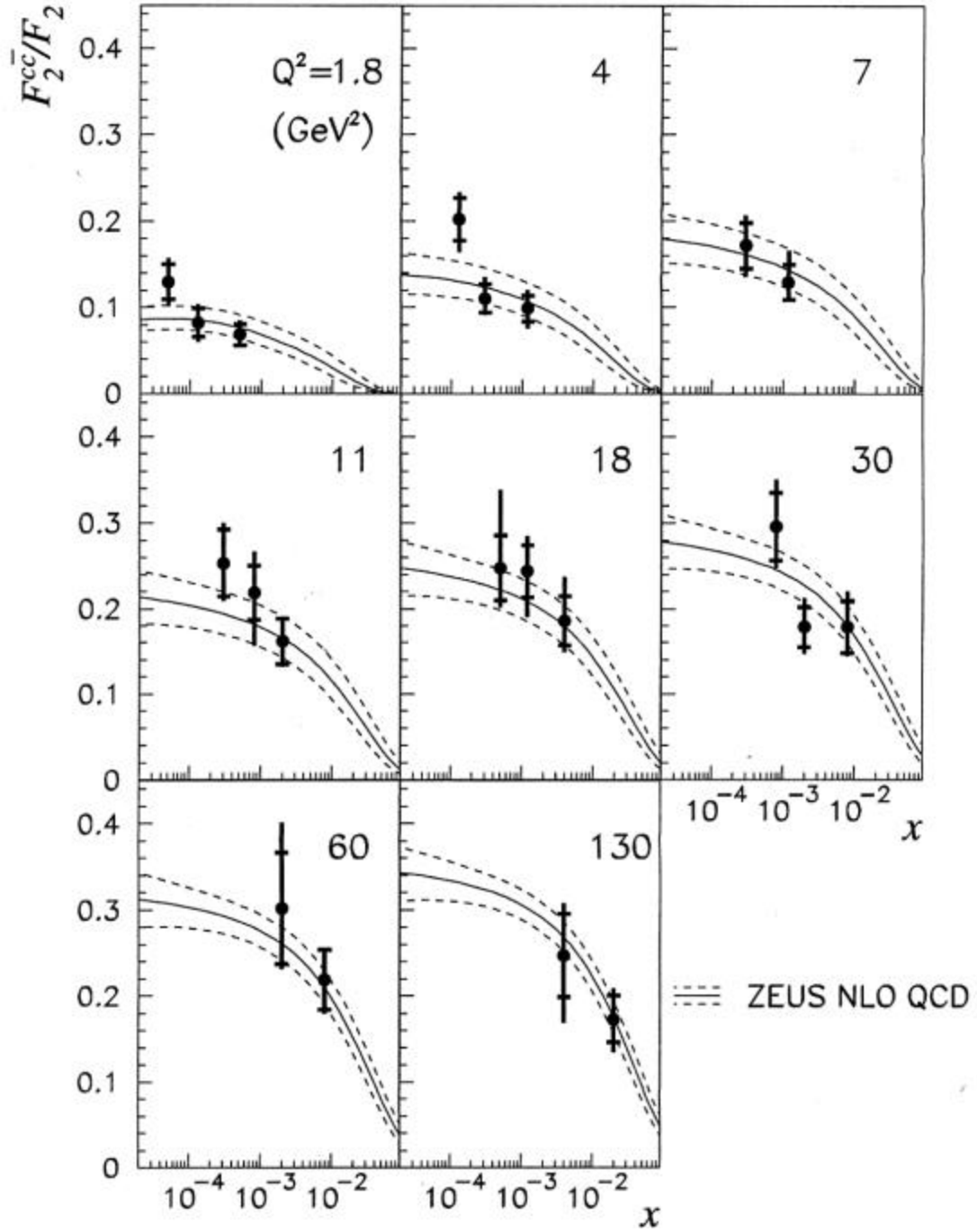


Figure 2. The ratio F_2^{cc}/F_2 at Q^2 values between 1.8 and 130 GeV^2 as a function of x . The curves correspond to NLO QCD calculations based on the ZEUS measurements of F_2 .

iii) *Measurement of the $E_{T, \text{jet}}^2 / Q^2$ Dependence of the Forward Jet Production at HERA*

The forward-jet cross section in deep inelastic e^+p scattering has been measured using an integrated luminosity of 6.36 pb^{-1} . The jet cross section is presented as a function of the ratio of the square jet transverse energy $E_{T, \text{jet}}^2$ and Q^2 . Since the perturbative QCD predictions are sensitive to the treatment of the $\log(E_{T, \text{jet}}^2 / Q^2)$ terms, this measurement provides an important test of its applicability in different regions of phase-space. In Figure 3 the measured cross section is compared to the predictions of a next-to-leading order perturbative QCD calculation as well as to a leading-order Monte Carlo model. Both predictions include a resolved virtual photon component and describe the data adequately over the entire range of $\log(E_{T, \text{jet}}^2 / Q^2)$. Models which do not include terms associated with a resolved virtual photon are able to reproduce the measurements at small values of $\log(E_{T, \text{jet}}^2 / Q^2)$, but fail to describe the high $\log(E_{T, \text{jet}}^2 / Q^2)$ region.

ZEUS 1995

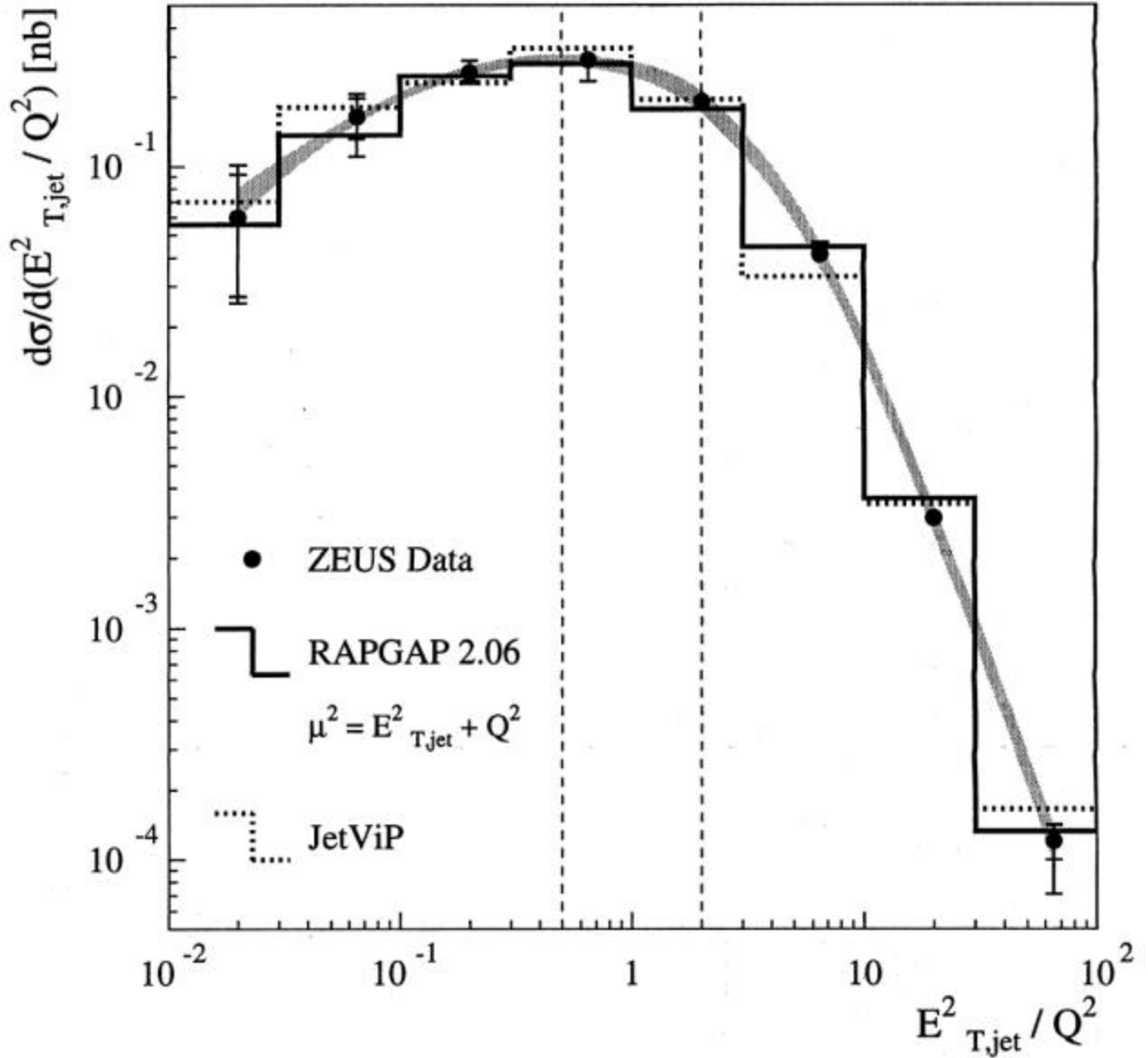


Figure 3. Forward jet cross section as a function of $E^2_{T,jet}/Q^2$. The data are compared to the RAPGAP Monte Carlo model with direct and resolved contributions (full histogram). The results of the NLO calculation JetViP are shown as the dotted histogram.

iv) Measurement of Dijet Photoproduction at High Transverse Energies at HERA

The cross section for dijet photoproduction at high transverse energies has been measured as a function of the transverse energies and the pseudorapidities of the jets. The measurement is based on an integrated luminosity of 6.3 pb^{-1} . Jets are defined by applying the k_T -clustering algorithm to the hadrons observed in the final state. The measured cross sections

are compared to next-to-leading order QCD calculations. In a kinematic regime where theoretical uncertainties are expected to be small, the measured cross sections are higher than the calculations, see Figure 4. The discrepancy observed between the data and the calculations suggest that, in the kinematic region of this analysis, the available parametrizations of the parton densities of the photon are too small. Predictions for a subset of events selected at high x_g , the momentum fraction of the parton in the photon partaking in the production of the dijet system, agree reasonably well with the measurements.

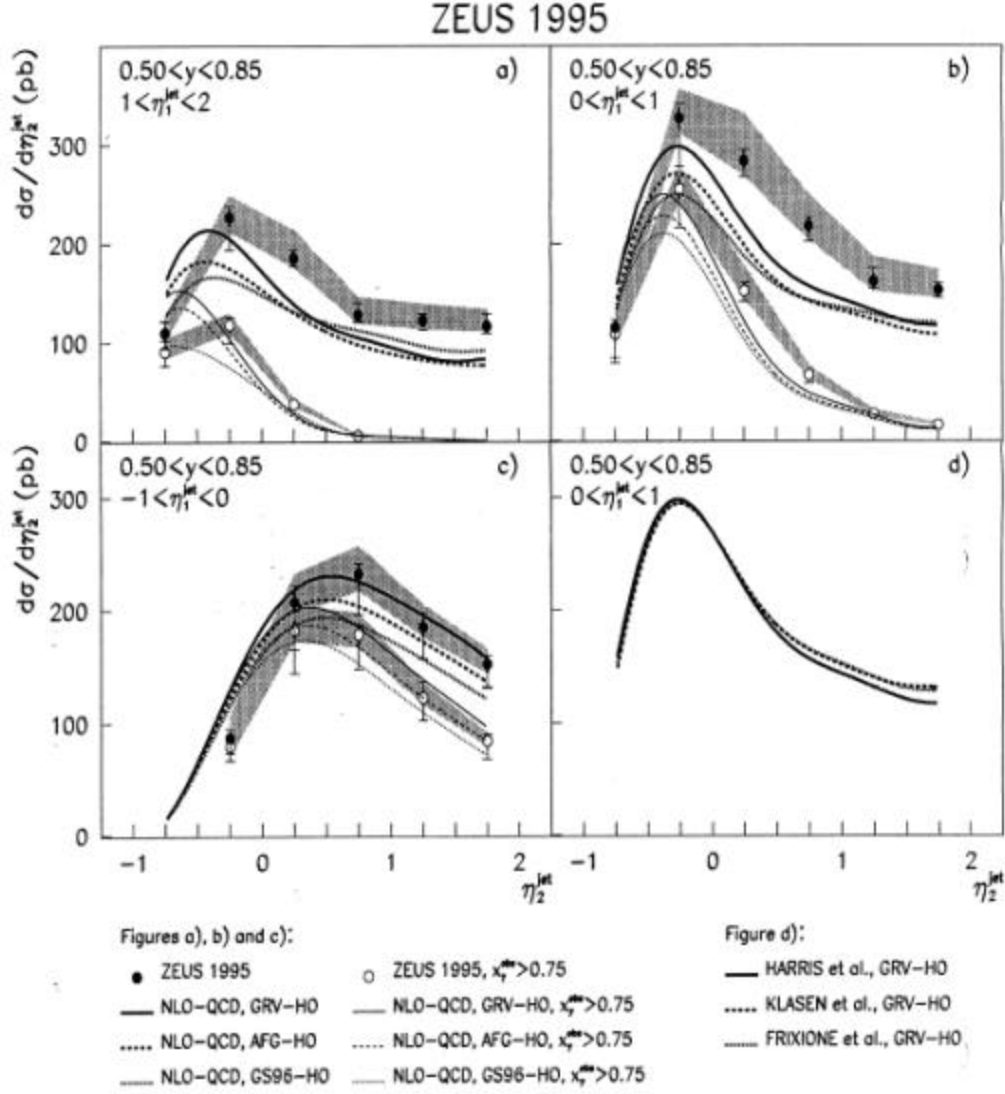


Figure 4. a), b) and c) show the dijet cross section as a function of h_2^{jet} in bins of h_1^{jet} and for $0.50 < y < 0.85$. The filled circles correspond to the entire x_g range while the open circles correspond to events with $x_g > 0.75$. The full, dotted and dashed curves correspond to NLO QCD calculations using the GRV-HO, GS96-HO and the AFG-HO parametrizations of the photon structure. In d) the NLO QCD results for the cross section when $0 < h_1^{jet} < 1$ and for a particular parametrizations of the photon structure are compared.

v) *Measurement of the Spin Density Matrix Elements in Exclusive Electroproduction of \mathbf{r}^0 Mesons at HERA*

Exclusive electroproduction of \mathbf{r}^0 mesons has been measured in two Q^2 ranges, $0.25 < Q^2 < 0.85 \text{ GeV}^2$ and $3 < Q^2 < 30 \text{ GeV}^2$. The low- Q^2 data span the range $20 < W < 90 \text{ GeV}$; the high- Q^2 data cover the $40 < W < 120 \text{ GeV}$ interval. Both samples extend up to four-momentum transfers of $|t| = 0.6 \text{ GeV}^2$. The distribution in the azimuthal angle between the positron scattering plane and the \mathbf{r}^0 production plane shows a small but significant violation of s-channel helicity conservation, corresponding to the production of longitudinally polarized (i.e. helicity zero) \mathbf{r}^0 mesons from transversely polarized photons. Measurements of the 15 combinations of spin-density matrix elements are shown in Figure 5. The results are compared to recent calculations of the amplitudes performed in the framework of perturbative QCD. The calculations are able to reproduce the measured amplitudes and the observed magnitude of s-channel helicity non-conservation.

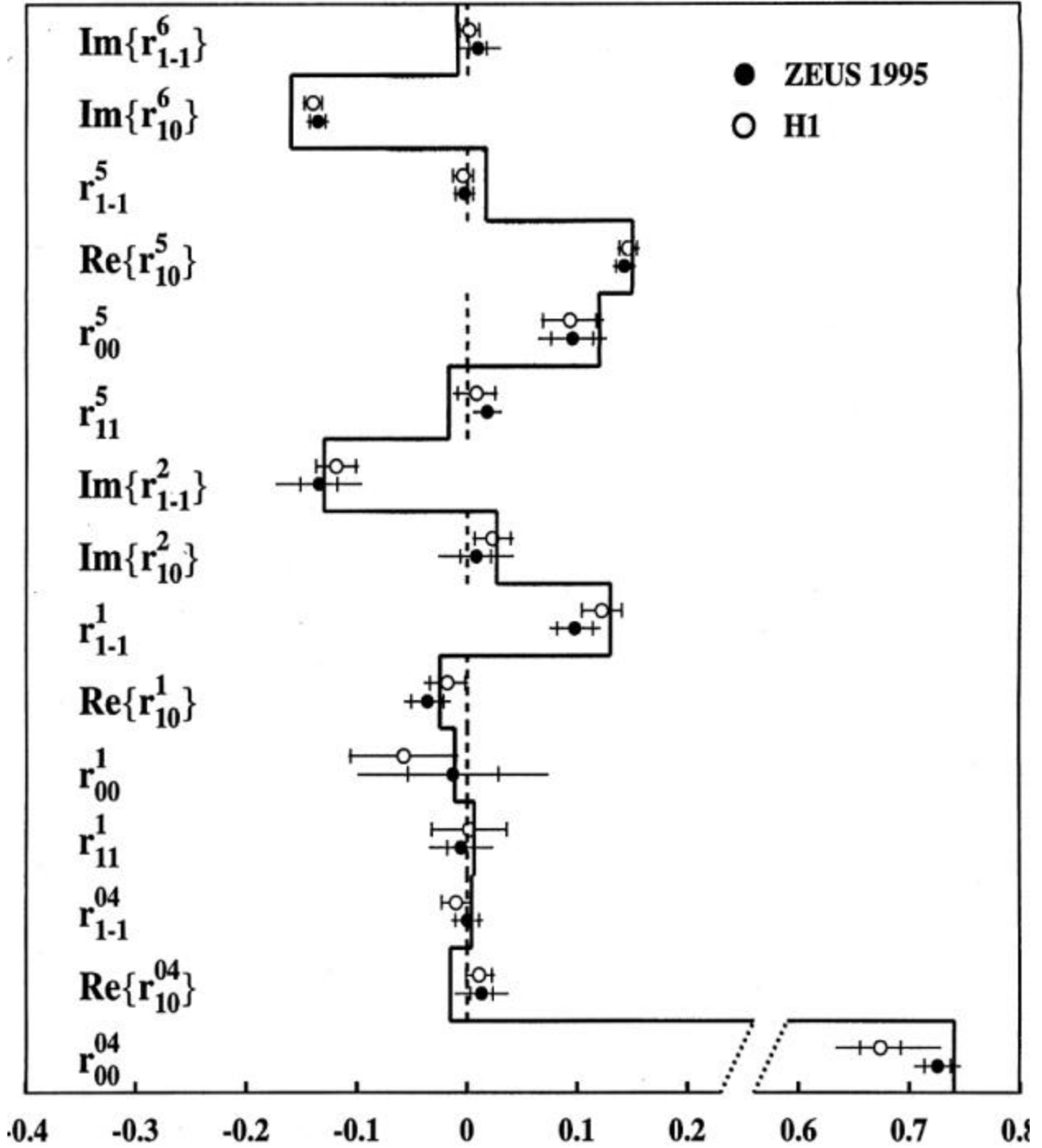


Figure 5. The 15 combinations of spin-density matrix elements, as obtained from the DIS data compared with the predictions of a model calculation based on perturbative QCD (continuous histogram) and of s-channel helicity conservation (dashed histogram). The solid (open) points indicate the ZEUS (H1) results. The ZEUS data cover the kinematic range $3 < Q^2 < 30 \text{ GeV}^2$, $40 < W < 120 \text{ GeV}$ and $|t| < 0.6 \text{ GeV}^2$.

vi) *W Production and the Search for Events with an Isolated High-Energy Lepton and Missing Transverse Momentum at HERA*

A search for the leptonic decays of W bosons produced in the reaction $e^+p \rightarrow e^+W^\pm X$ has been performed using an integrated luminosity of 47.7 pb^{-1} . Three events consistent with $W \rightarrow e\mu$ decays were found, giving a cross section of $0.9_{-0.7}^{+1.0} \pm 0.2 \text{ pb}$, in good agreement with Standard Model predictions. The corresponding 95% C.L. upper limit on the cross section is 3.3 pb. A search for the decay $W \rightarrow \mu\mu$ has a smaller selection efficiency and yields no candidate events. The resulting 95% C.L. upper limit on the cross section for this reaction is, somewhat weaker, at 3.7 pb.

b. HERA and ZEUS Operations

In the first half of calendar year 2000, HERA continued the positron run commenced in 1999. The machine performed exceptionally well and delivered collision rates corresponding to a total luminosity of almost 50 pb^{-1} . The run is planned to continue until the first week of September after which the machine will undergo an upgrade with the goal of obtaining higher luminosities.

The ZEUS detector performed well in this period. The recently added components, such as the forward plug calorimeter and the barrel presampler, were fully operational.

Progress on the several upgrade projects for the high luminosity period was satisfactory.

Both major tracking upgrade projects, the Microvertex detector and the Straw Tube Tracker for the forward region, claimed to be able to meet the tight schedule imposed by the DESY management.

(J. Repond)

I.B. EXPERIMENTS IN PLANNING OR CONSTRUCTION

I.B.1 MINOS -Main Injector Neutrino Oscillation Search

The MINOS experiment is designed to search for, and (hopefully) to study neutrino oscillations with sensitivity significantly greater than has been achieved by previous experiments. The phenomenon of neutrino oscillations allows the three flavors of neutrinos to mix as they propagate through space or matter. The MINOS experiment is optimized to explore the region of neutrino oscillation parameter space (values of the Δm^2 and $\sin^2(2\theta)$ parameters) suggested by previous investigations of atmospheric neutrinos: the Kamiokande, IMB, Super-Kamiokande and Soudan 2 experiments. The study of oscillations in this region with an

accelerator-produced neutrino beam requires measurements of the beam after a very long flight path. This in turn requires an intense neutrino beam (produced for the MINOS experiment by the Fermilab Main Injector accelerator) and massive detectors. The rates and characteristics of neutrino interactions are compared in a “near” detector, close to the source of neutrinos at Fermilab, and a “far” detector, 735 km away in the underground laboratory at Soudan, Minnesota. The neutrino beam and MINOS detectors are being designed and constructed as part of the NuMI (Neutrinos at the Main Injector) Project at Fermilab.

The MINOS detectors are steel-scintillator sandwich calorimeters, with toroidally magnetized 1-inch thick steel planes. The combination of alternating active detector planes and magnetized steel absorber planes has been used in a number of previous neutrino experiments. The MINOS innovation is to use extruded plastic scintillator with fine transverse granularity (4-cm wide strips) to provide both calorimetry (energy deposition) and tracking (topology) information. The 5,400 metric ton MINOS far detector is also much more massive than previous experiments. Recent advances in extruded scintillator technology and in pixilated photomultipliers have made such a detector feasible and affordable for the first time.

Results from Super-Kamiokande, Soudan 2 and MACRO experiments provide increasing evidence that neutrino oscillations are taking place in just the regions of parameter space that MINOS was designed to explore. This has provided mounting impetus to go forward with MINOS as expeditiously as possible. Indications from Super-Kamiokande data that the value of Δm^2 is around $3.5 \times 10^{-3} eV^2$ have led to the design of a lower energy beam for MINOS, to improve sensitivity at low Δm^2 . Argonne physicists and engineers have been involved in several aspects of the preparations for MINOS: scintillator-module factory engineering, near-detector front-end electronics, far-detector installation and the use of the Soudan 2 detector with the NuMI neutrino beam (also known as Theseus).

One major focus of work by the Argonne MINOS group is scintillator module production. Argonne has completed the engineering designs and prototyping of critical parts of the scintillator detector system, including the semi-automated machines and tooling needed for mass production of scintillator modules. (MINOS detector “modules” are subassemblies of 20 or 28 scintillator strips.) This production will take place at “factories” located at Caltech, the University of Minnesota and at Argonne (where all near detector modules will be constructed). Argonne physicists and engineers serve as NuMI Project Level 3 WBS Managers for the design and construction of the machines needed to construct scintillator modules and for the operation of the module factories. Previously, an Argonne physicist served as the Level 3 manager for scintillator strip fabrication and was responsible for the introduction of several important strip design innovations. Argonne constructed a prototype production facility for scintillator “modules” in Building 366, which was used in July 1999 and May 2000 to produce prototype scintillator modules for evaluation of production procedures as well as for performance studies in the Fermilab 4-plane prototype setup. The 4-plane prototype is a full-size assembly of MINOS far-detector steel and scintillator planes that has been in operation since late 1999. Following the May 2000 prototype production run, Argonne began construction of the assembly machines and tooling for the Caltech module factory.

The second major focus of the Argonne MINOS group is electronics and data acquisition for the experiment. Argonne physicists and engineers serve as the Level 2 manager for electronics and the Level 3 manager for near-detector front-end electronics. The 1999 decision to use single turn extraction (STE) from the Main Injector for the NuMI neutrino beam motivated the change to the current design of the near-detector front-end electronics, which is based on the Fermilab QIE asic chip. During the first half of 2000, prototype QIE chips were designed and produced, and will be evaluated by Fermilab and Argonne engineers as soon as the test setup is completed. These chips operate at 53 MHz and have no digitization deadtime, which is essential for operation at the high instantaneous rates produced by STE. Argonne engineers have also completed the initial design of the MINOS MASTER module, which receives and processes data from the QIE chips.

An Argonne physicist also serves as Level 2 manager for far detector installation. Far detector installation work during this period involved close interaction with the architect-engineering firm, CNA Consulting Engineers, and with MINOS collaborators at the University of Minnesota, on the design of the cavern infrastructure. Excavation of the MINOS far-detector cavern at Soudan began in May 1999 and is scheduled to be complete in November 2000. Infrastructure installation is scheduled for completion in May 2001, and will be followed by the installation of the 5,400-ton far detector. Evaluation of bids for the infrastructure construction began at the end of June 2000. The Argonne installation group also continued to work on the design of installation procedures for the detector at Soudan, in close collaboration with the University of Minnesota, Fermilab and CNA.

Finally, Argonne physicists are heavily involved in an evaluation of the sensitivity of the Soudan 2 detector for the study of neutrino oscillations in the NuMI beam. In this context, the Soudan 2 detector is referred to as Theseus (The Second Experiment Underground at Soudan). The MINOS collaboration has established a Theseus working group, led by an Argonne physicist, to examine the physics and technical issues relevant to this use of the Soudan 2 detector as part of the MINOS experiment. The group is performing simulations to compare the oscillation sensitivities of Theseus and the main MINOS experiment. The following oscillation tests are under study: (1) the NC/CC ratio, (2) electron identification (from ν_e appearance and from ν_τ CC interactions followed by tau to e decay), (3) tau identification using recoil proton information, and (4) measurement of Δm^2 using the ν_μ CC event energy spectrum. The group is also examining the importance of a possible near detector for each of these studies.

See Section I.A.3 for an in-depth report on Theseus.

(D.S. Ayres)

I.B.2 ATLAS Detector Research & Development

a. Overview of ANL ATLAS Tile Calorimeter Activities

The TileCal subsystem continued making excellent progress in the first half of 2000. Module construction is proceeding on schedule and all of the early problems are behind us. In addition, we have reached the halfway point in submodule construction. Early problems with the instrumentation of modules with scintillators and fibers slowed this work somewhat. However, by the end of June 2000, most problems were close to being resolved and progress is expected to pick up through the summer when we expect to achieve our planned instrumentation rate of 1 module per calendar month. Finally, the first 6 modules were tested at Argonne and at Michigan State University and shipped to CERN. Figure 1 shows the first of these being unwrapped at CERN.



Figure 1. Unwrapping the first production extended barrel module delivered to CERN.

(J. Proudfoot)

I.C. DETECTOR DEVELOPMENT

I.C.1 The CDF Upgrade Project

Shower max calorimeter readout continues to be a major project for us. Karen Byrum is project manager and Gary Drake is Chief Engineer, and John Dawson has taken on several of the components. All of the multiple card components except the pre-amplifier have gone into production. A preamplifier design has been tried with a few channels on our local test setup and looks promising. Jim Proudfoot is working on testing and internal programming development for the VME readout boards "SMXR." Steve Kuhlmann is continuing to develop software to handle the hardware within the B0 online system. Karen continues working with Gary to develop the amplifiers needed for the wire chamber shower max readout. The current seems very promising for meeting the noise specs, as illustrated in the clean ^{55}Fe peak of Figure 1. The final testing will be done in conjunction with the CDF engineering run scheduled for late summer with two central wedges and some plug instrumentation to be installed.

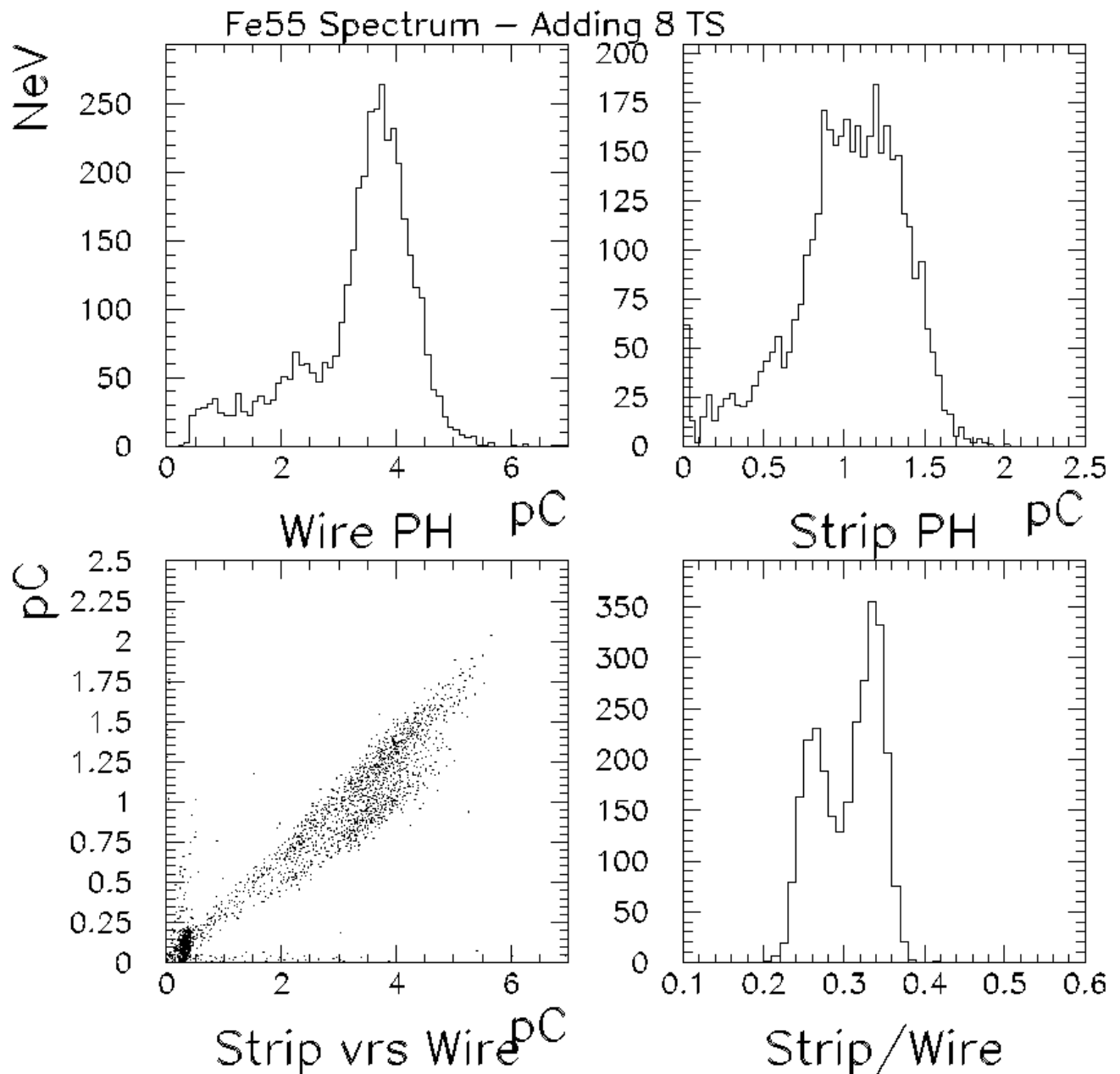


Figure 1. Response of the central shower max test chamber to x-rays from ^{55}Fe in both strip and wire views as well as the correlation. In this case, eight time slices are summed, making the measurement quite noise sensitive.

Karen and John have been working with the Michigan group to prototype the shower max Level 2 trigger bit input card; this has been demonstrated using level 2 emulation and a production version has been started. Steve, John and Bob Blair have prototypes of isolation trigger electronics, which have been tested with the level 1 calorimeter input cards.

Larry Nodulman has continued working on shielding wire chamber signal cables and redoing grounding. The last crack chambers, which had high voltage problems, were replaced. Steve Kuhlmann has been coordinating the new gas feed system for the wire chambers.

Bob Wagner and Randy Thurman-Keup are developing offline software for calorimeter reconstruction with emphasis on electron code. Bob, Steve and Barry Wicklund are involved in code for the wire chamber data reconstruction. Bob Wagner has completed the program of fixing the bases and checking the tubes for the central EM calorimeter.

Randy Thurman-Keup has developed high voltage control for wire chambers other than COT, that is muon chambers as well as preshower, shower max and crack chambers in our calorimeter. Good progress continues on the muon upgrade, under the oversight of Tom LeCompte, with new front-end electronics and new chambers being completed and installed. In general the CDF detector is coming together fairly well for the coming test run.

(L. J. Nodulman)

I.C.2 ZEUS Detector Upgrade

a. Straw Tube Tracker Readout Electronics

ZEUS plans to install a new forward tracking detector during the 2000/2001 machine shutdown. The new tracker is based on the straw tube technology and will consist of 48 sectors containing a total of 12,000 tubes. It is expected to greatly improve the detectors ability to measure high Q^2 neutral current events, to determine charged current event vertices, to tag heavy flavor decays in the forward direction, and to track charged particles in general. The detector is being built by a group of nine institutions which are all part of the ZEUS Collaboration.

The Argonne group took over the responsibility of designing and building the front-end electronics consisting of shapers, discriminators, a multiplexing and a cable driver circuit. The multiplexing is necessary to match the 12,000 channels of the new detector to the 2,000 channel read-out system of the current forward detector.

As a first step, Argonne built a prototype board containing the two-threshold ASDBLR chip developed by Penn University to shape and discriminate the signals and a circuit to drive the standard 42 m signal cable employed by the experiment.

Based on experience gained with the first prototype, a second prototype was built using the ASDQ chip which contains a one-threshold discriminator. The second prototype contains all elements of the readout system including the multiplexing circuitry and is very similar to the final production electronics. Extensive tests of the second prototype were performed in order to understand the threshold setting circuitry and the on-board pulser. Final adjustments were made

before initiating production of both the main boards (containing the discriminators and multiplexing circuitry) and the cable driver boards. The latter will be produced by Tel-Aviv University.

(J.Repond)

I.C.3 ATLAS Calorimeter Design and Construction

The ATLAS tile calorimeter construction effort is now fully into the production phase. The areas of ongoing work comprise: submodule construction; module assembly; instrumentation and testing; testbeam measurement of detector performance; engineering support of work at US collaborating institutes; continued engineering evaluation of specific elements of the detector and final design of areas in the detector where special constraints such as the support of the liquid argon cryostats must be accommodated.

a. Submodule Construction

Submodule production continued at the scheduled production rate as is shown in Figure 1. At the close of this reporting period, 96 submodules were stacked and welded, 93 painted and 93 fully completed and stored for mounting into modules. The height envelope for all submodules constructed to date is shown in Figure 2. Mostly, the submodules fully meet the specification and the general trend is towards more uniform construction. There was a minor problem with controlling the height of the special submodules, which resulted in 10 of them falling above the maximum allowed height. This has now been corrected on the stacking fixture. However, the submodules themselves are completely useable without requiring any special attention during module assembly. Finally, production at the other two U.S. institutions is also proceeding well and the early schedule delays are being made up.

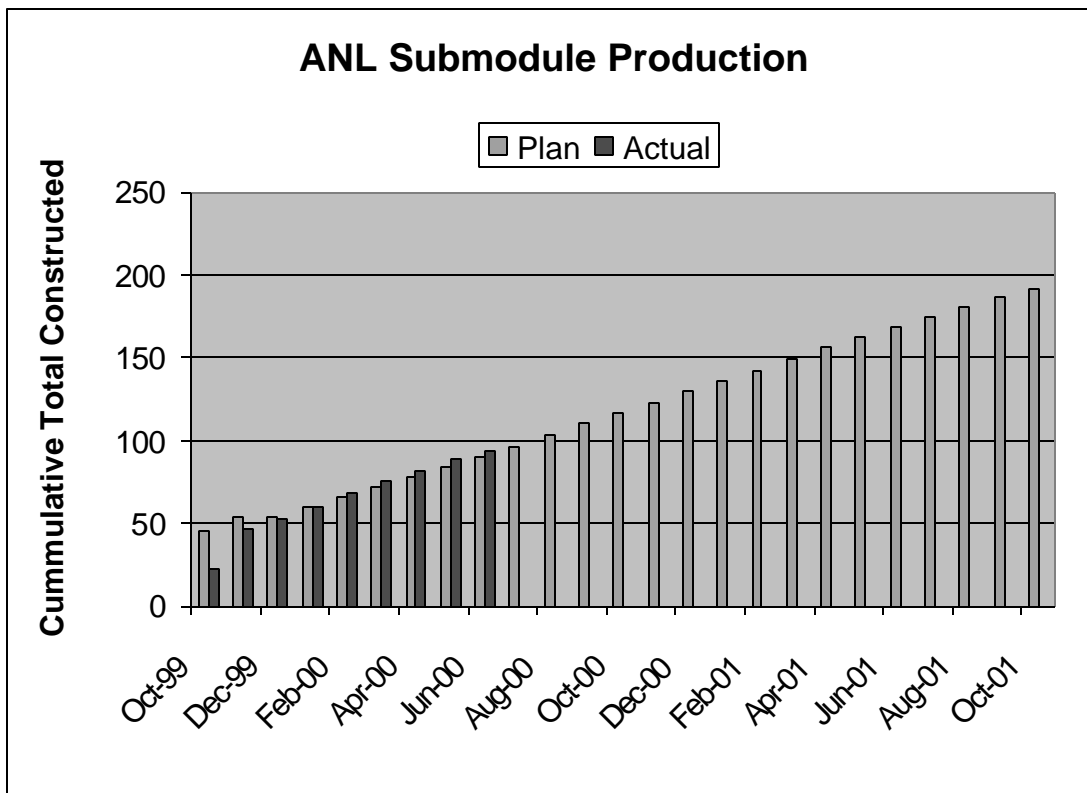


Figure 1. Submodule production at Argonne compared to baseline schedule.

b. Module Assembly

Module production is also proceeding smoothly and at a somewhat higher rate than planned in the baseline schedule. A cumulative total of 12 modules have been constructed to date. The timely delivery of the special ITC submodules from the University of Texas at Arlington was a concern during the early part of the production. However, after some effort and assistance from Argonne engineering staff in resolving a few technical problems, this has been overcome and we are now regularly constructing on average one module every 2 calendar weeks. As a result we have been able to recover some of the schedule slippage resulting from the late start. All assembly and quality control procedures are now routine and the tooling developed in late 1999 has proven to be very effective and efficient to use. A particular concern is the azimuthal envelope for the detector and the assembly and QC protocols pay particular attention to its control and evaluation. The envelope is established during module construction by accurately aligning submodules using an optical transit, and verified after construction by estimate of plumb-line perpendicularity and measurements of feeler gauge planarity using a 1.6m straight edge as a reference. These data are shown in Figure 2, which shows that we are well within the design envelope of +0.030 inches (+0.75mm).

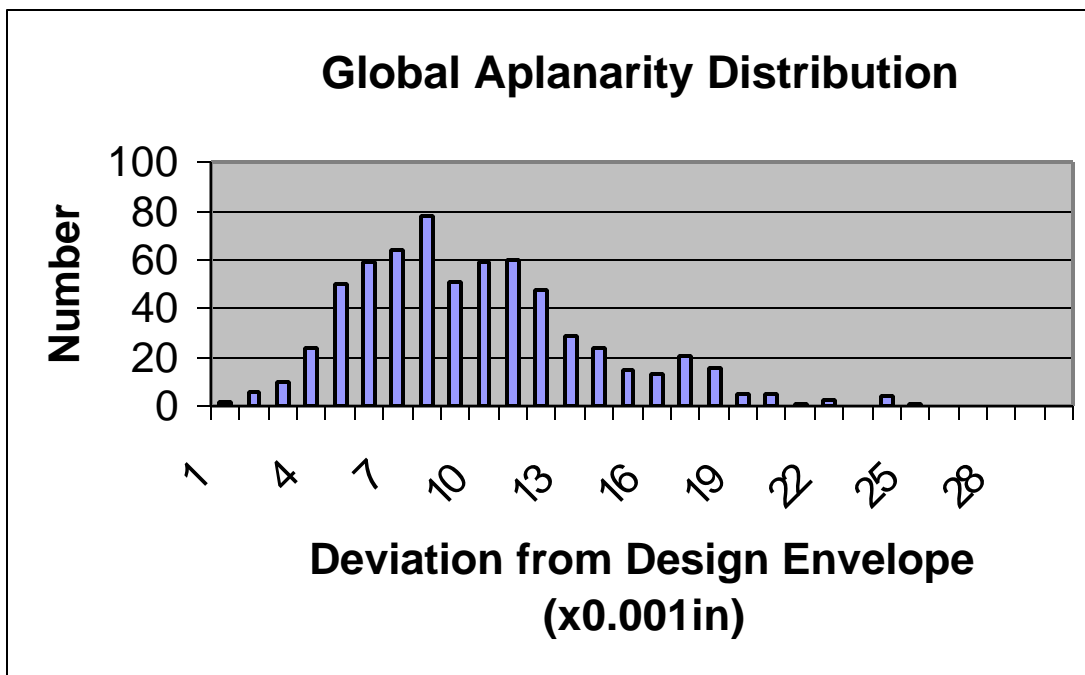


Figure 2. Module envelope deviation from design specification.

Construction and delivery of the other main structural component, the structural girder, has not proven to be a limiting factor in the module construction rate. To date, 26 girders have been constructed and delivered by the vendor, routinely at a faster rate than required to meet the module construction rate (8 per 4 calendar months). These girders have precision surfaces, which are integral to the successful realization of the envelope specification. We have therefore

established, at the vendor, a witness inspection of each batch of 8 girders prior to accepting delivery. A few minor deviations from specification have been encountered and reported to the vendor for the correction of that of future girders. However, all girders produced up to this point have been accepted. Given the importance of this element in the calorimeter structure, this site inspection is planned to continue.

(J. Proudfoot)

c. Instrumentation and Testing

A key challenge in this period was to master the task of module instrumentation with plastic scintillator tiles and wavelength shifter fibers and, many new tasks, as well as tasks performed during instrumentation of the prototype module, had to be re-learned. The issues included:

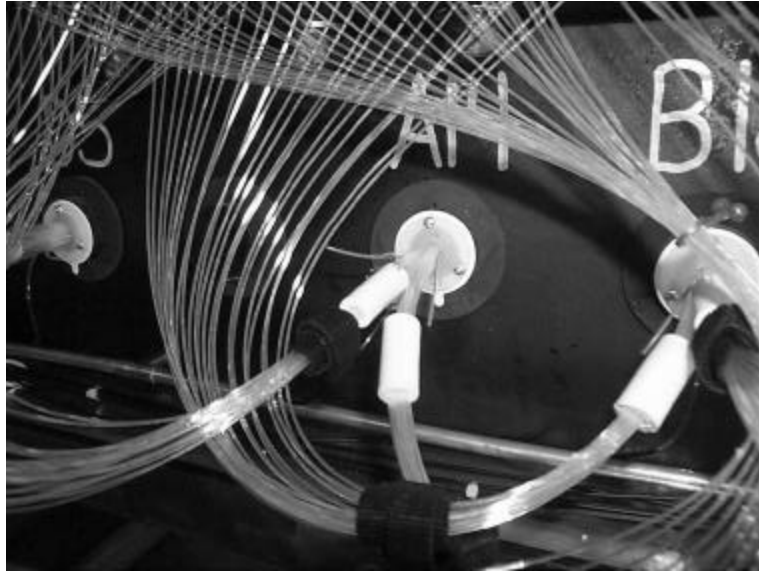
- Fiber routing scheme and procedures, templates and photographs as aids in realizing reproducibility
- Use of an LED bar for verification of fiber routing before gluing in the fiber bundles
- Development of profile installation tools, as well as tools to ensure that the grooves were sufficiently wide to accommodate the profiles
- Development of techniques for fiber bundle repair after gluing
- Development of techniques for single fiber repair after gluing
- Technique and materials (clips, straps and bands) required to tie back fiber bundles within the module envelope
- Training of technicians in the details of these complicated tasks
- Development of software to take and analyze cesium source data
- Scintillator quality control and sorting (after we discovered an unacceptable level of variation in response, in the first 2 modules instrumented at Argonne)

With the above learning experience, we have now established a relatively routine set of procedures (by using checklists) for module instrumentation. The entire set of tasks is now being accomplished in about 5 calendar weeks per module using a crew of 2 technicians and 1 EA. Of the above tasks, two in particular are worth some additional description: fiber and fiber bundle repair; the cesium scans used to determine module uniformity.

Since approximately 2000 fibers are installed per module and the routing and installation tasks are complex, it was essential to develop some techniques for repairs after the cesium source scan identified problems with fiber or tile couplings. After some initial tests using splicing of fibers, our collaborators in Europe and at Michigan State University proposed the use

of Teflon rods to allow a straightforward repair of a single fiber. The final version of this is shown in Figure 3a, where the short filaments seen in this photograph are orange Teflon rods. These are inserted as part of the fiber gluing. Should replacement of a single fiber prove necessary, the Teflon rod is easily drawn out and a replacement fiber glued in its place. In addition, the tool shown in Figure 3b allows us to mill down the plastic insert in which the aspirin tube is located and thereby re-cut a fiber bundle by as much as 15mm. With these two repair techniques, it is possible to ensure that all fiber couplings meet our design goal.

a)



b)



Figure 3. Fiber and fiber bundle repair techniques: a) single fiber repair using Teflon rods, b) fiber bundle repair by milling plastic girder ring insert.

One of the other key tasks in the instrumentation is the use of a cesium source to measure the response of every tile-fiber coupling in the calorimeter. Semi-automatic software developed to operate the source, read out the phototubes, analyze the output data and produce a list of suspect tile-fiber couplings (presently generated for any coupling whose response is less than 70% of the average value in that row). A typical source scan is shown in Figure 4. The two plots are the response from phototubes reading out opposite sides of the same set of scintillator tiles. This data is unfolded to obtain an estimate of the response for each coupling, from which an average uniformity of the calorimeter response can be obtained. For the first two modules, the uniformity was 8-10% and, therefore, too close to the maximum specified of 10%. However, the Argonne group using the source data, determined that a large contribution was coming from a systematic variation of light from the scintillator tiles themselves, i.e. not intrinsic to the quality of the instrumentation process. This was understood and has been easily corrected by a careful sorting of groups of tiles using QC data obtained during their manufacturing. Since adopting this procedure, the uniformity is now better than 6%.

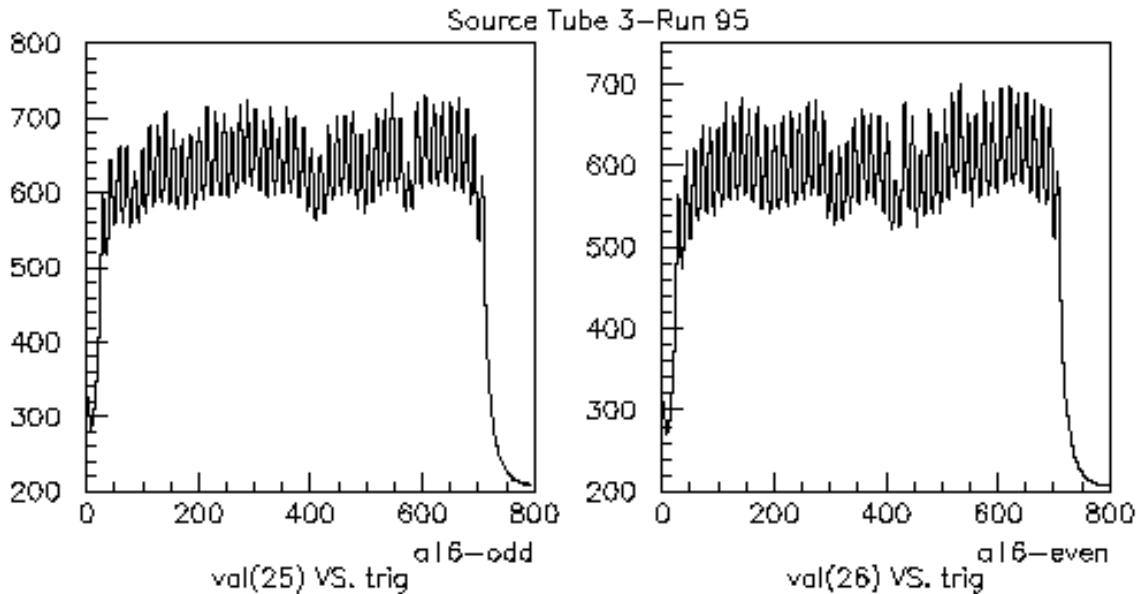


Figure 4. The photo-multiplier response in a typical cesium source scan in one tile row of the calorimeter. The peaks and valleys in the response occur as the source traverses the scintillator and steel plates in the calorimeter.

(J. Proudfoot)

d. Test Beam Program

An Argonne staff physicist continues to be the coordinator of the TileCal testbeam program. In addition, a HEP Division computer scientist was enlisted to develop readout code for the new online data acquisition system. Late April and early May saw the installation of the on-board digitizers on Module 0. But because these were not final electronics, the April-May period was used mainly to commission the new DAQ.

The CERN prototype ATLAS DAQ-1 was installed for the first time ever in the TileCal counting room. The continuing development of the acquisition package was developed in collaboration with CERN, Argonne, and IHEP using the detector information and trigger requirements from the TileCal testbeam users. Further tuning will proceed throughout the next two testbeam periods.

In addition, the structure of the DAQ-1 did not allow for individual RODs to record the trigger type or BCID of the event. In conjunction with the electronics group, HEP physicists collaborated in the design of a ROD controller-based PMC card, the TTCpr, which would decode the TTC information and make it available to the RODs in the crate. The RODs then pass that information to the Event Builder, which concatenates events with the same BCID. The design was finished and the hardware certified in the lab, but because of the lack of TTCrx chips, use is not allowed until the July period.

(R. Stanek)

e. Engineering and Design



Figure 5. A submodule cut using a band saw as a test of the use of this approach in fabricating the special submodules needed in the region of the cryostat supports.

We completed the test cutting of a submodule on a band saw as a technique for the fabrication of the special submodules needed in the region of the cryostat support (Figure 5). The test achieved its goal and we now have a working basis from which to start the final design of these submodules. The general approach has been adopted by the TileCal collaboration and will be to first, rough cut a standard submodule on the band saw, then finish to dimension on a mill. Following this, an additional stiffener plate will be welded on. Overall, this will be a relatively cheap solution to the problem of constructing the several different geometries of special submodules needed for the region of the cryostat supports.

The discussion question concerning stresses in the threads of the weld bars that connect submodules to the girder has been concluded. An Argonne engineer prepared a final summary document, covering the analysis by the four lead engineers in the collaboration. The analysis and conclusions were reviewed at February Atlas Week, where it was concluded that the number of bolts should be increased from 3 to 5 on the submodules carrying the largest loads (a total of 24 submodules per extended barrel calorimeter).

Argonne scientific and technical staff has continued to back the supported submodule construction activities at other US collaborating institutions that include:

- welder certification and WPS process assistance
- ITC construction and quality control
- site checks of submodules at UI & UC
- submodule quality control monitoring



Figure 6. New fixtures to be used for the construction of ITCs being checked and tested on the stacking fixture at Argonne.

Of particular note is the work done by Argonne technical staff to assist the group at the University of Texas at Arlington in constructing the special ITC submodules. About one-half of the plates required for this assembly were incorrectly cut by a vendor such that it was impossible to maintain the submodule envelope on the standard stacking fixture. Argonne technical staff designed tooling to restrain the plates on the edge rather than at the inner radius key to effect an “as built” control on the exterior envelope. These fixtures (shown in Figure 6) were fabricated at Argonne and tested on our own stacking fixture prior to being shipped to UTA where our staff assisted the UTA group in their installation. This has been very successful and it is now the standard procedure for the stacking of these submodules.

f. Module Shipping

Figure 1 in Section I.B.2 shows the scheme finally adopted for the shipment of modules to CERN, which was the result of several months of consultation with a shipping broker and packaging companies. Our basic problem was to find a safe way to send modules to CERN without using the custom container that was used for shipping the prototype module there. This latter approach was successful, but due to the size of the container and the need to pay for the return of the empty container, the cost would have been prohibitive for production shipping of modules. We therefore investigated schemes using standard

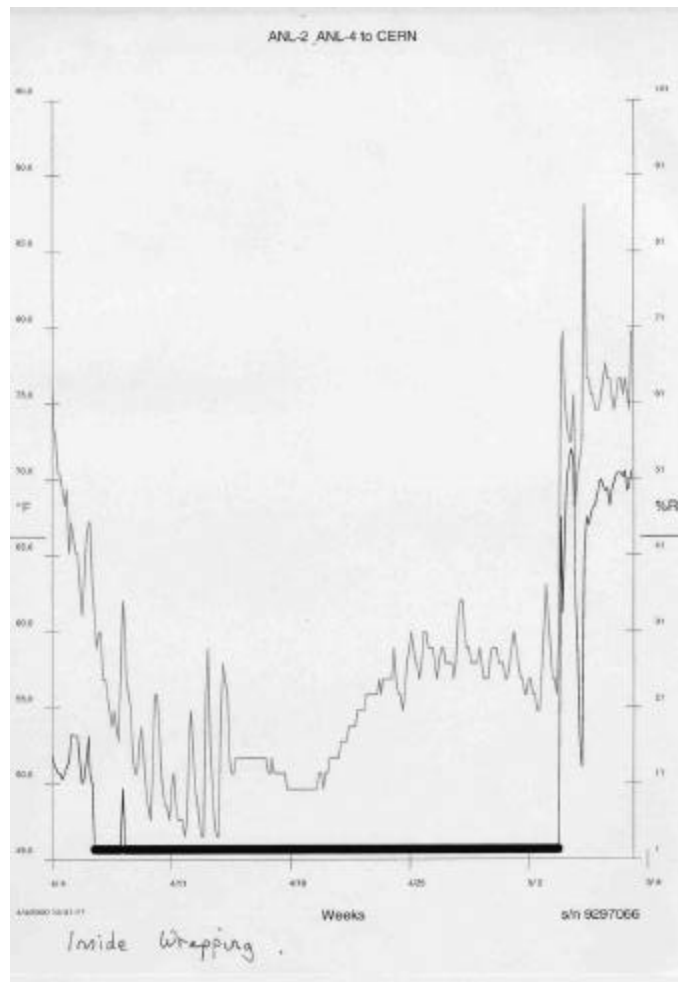


Figure 7. Temperature and humidity around module during transportation.

containers and chose also to investigate the use of a commercial packager. The net result was that we chose to send two modules simultaneously in a standard 40ft close-topped container. Each module is mounted on a wooden skid, which is simply blocked and braced in the container. The modules are also shrink- and vacuum-wrapped with a vapor barrier (the shiny aluminized Mylar seen in Figure 1 of Section I.B.2). Some minor problems were encountered while pushing the first pair of modules into the container, but these have now been corrected by adding some

plastic runners to the base of the skids. The vapor barrier was excellent in preventing any humidity around the module during transport as is seen in Figure 7. This shows temperature and humidity measured by sensors mounted inside the wrapping, the rapid increase towards the end of the time line is when the module was unwrapped at CERN. The outside humidity was close to 100% for the entire duration of the transportation. Three shipments have been made and the process is now quite routine. The cost savings to the project resulting from this work were very substantial (about \$300,000).

(J. Proudfoot)

I.C.4 Computational Projects

a. ATLAS Computing

Argonne assumed joint leadership of the ATLAS database development effort just before the start of calendar year 2000. A fundamental priority during this reporting period was the organization of the database domain, which broadly includes not only a multi-petabyte event store, but also databases for time-varying information such as calibrations, run conditions, slow control information, and alignment. The database domain is responsible as well for most detector description software, and for substantial components of the ATLAS event model. A PBS, effort estimates, a near-term workplan, and a census of available effort were undertaken and continue to evolve; these have been used as input to the process of WBS development for the global ATLAS computing effort, and to LHC-wide and U.S. reviews. Organizational and technical contributions were made to two ATLAS detector description workshops, and to two event model workshops as well.

Part of the detector description effort revolved around using the XML meta-language to describe the geometry of the ATLAS detector, and Argonne focused on describing the tile calorimeter in this language (Figure 1 shows a visualization of part of the calorimeter). This strategy allows us to use a common set of tools to create, test and visualize the detector description for each subcomponent of ATLAS, even though the content of each description varies widely.

Computational grids, which represent a vision of the future of high-performance distributed computing infrastructure, are beginning to play a role in the direction of the evolution of ATLAS computing, and in HEP computing more generally. Argonne collaborates in the Particle Physics Data Grid (PPDG), both representing ATLAS and convening the Applications Working Group, where "Applications" here means high energy and nuclear physics. ATLAS work within PPDG has centered on tools for and tests of grid-enabled replication and distribution of Objectivity/DB databases. Approximately 100 GB of tile calorimeter testbeam data is being used as the subject of these experiments.

Because data distribution and replication will be among the earliest grid-enabled applications inside ATLAS, and because globally distributed data will be key to the success of the ATLAS regional center/distributed computing model, Argonne has also led ATLAS planning for grid connections to offline software development, and has participated in planning to coordinate mock data challenges with grid research and development timetables.

A pilot project undertaken by Argonne in 1999 in collaboration with Protvino to provide access to tile calorimeter testbeam data remains the only production use in ATLAS of Objectivity/DB, the candidate database technology for the ATLAS event store. (Figure 2 shows the energy deposited in the calorimeter for a beam of muons and a beam of pions.) During the reporting period, the ATLAS architecture team proposed to use this work as a starting point for development of a detector description store, for support of event views (ways to access event data that are different than the way the data were stored), for understanding alternative approaches to transient/persistent separation, and for the first connection of Objectivity/DB data to the control framework. Work began on making these connections during the reporting period, and is scheduled for completion in the second half of the calendar year.

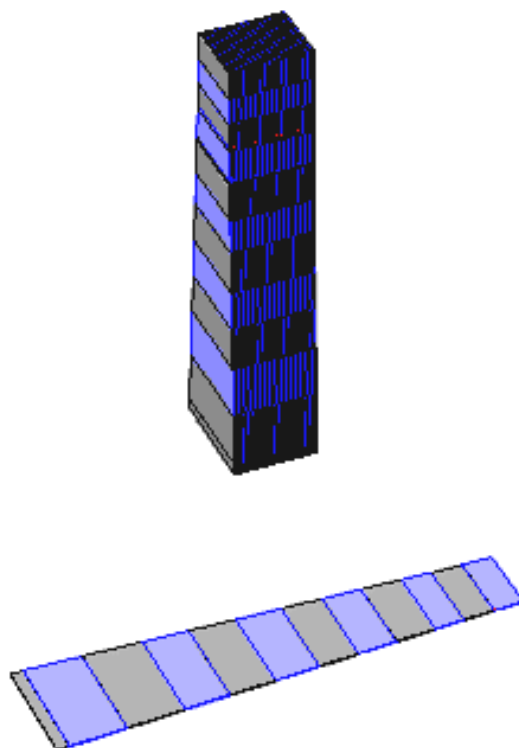


Figure 1. A visualization of parts of the Tile Calorimeter as described in the XML language.

Argonne and LAL/Orsay jointly organized an effort to evaluate IT-provided software in the context of liquid argon and tile testbeams. This work is ongoing, and is expected to lead to development of software that is common to several experiments, including, currently, ATLAS, LHCb, and COMPASS.

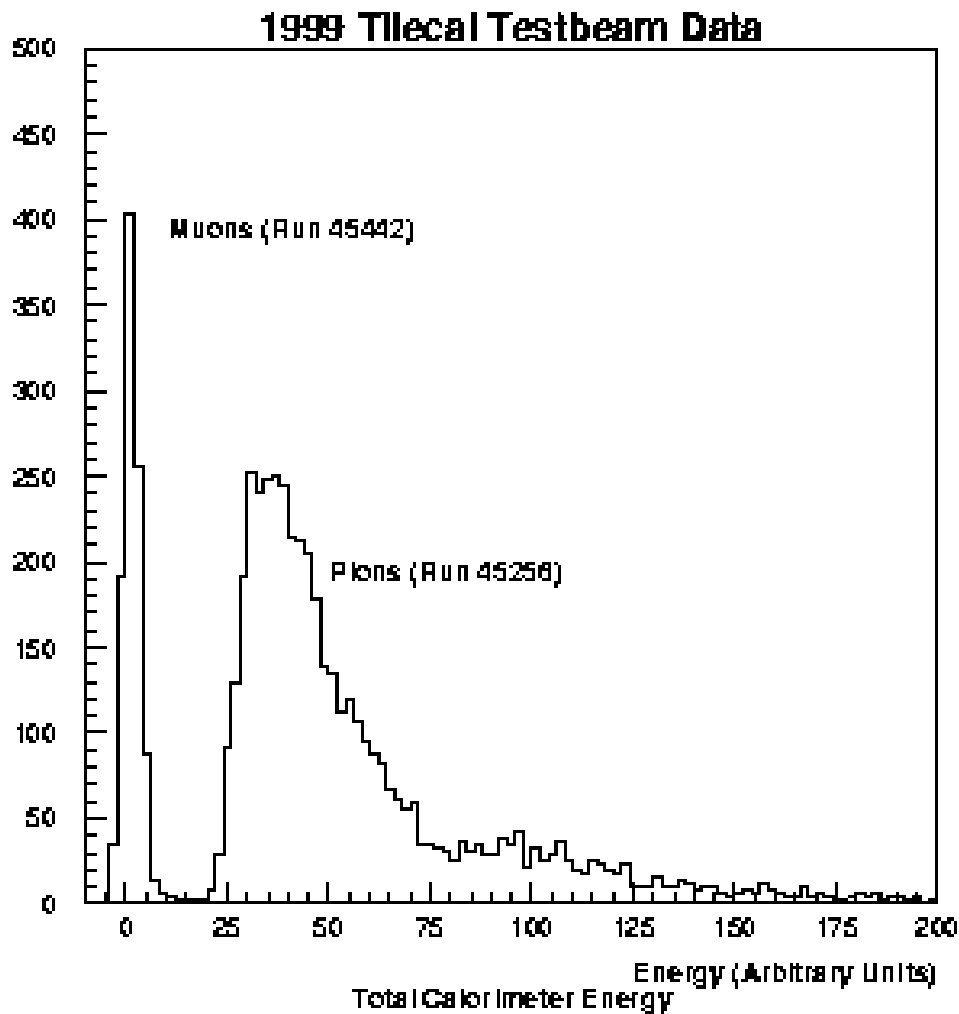


Figure 2. Energy deposited in the tile calorimeter from beams of pions and muons. The data used in making this histogram was extracted from the Objectivity database described in the text.

(T. LeCompte)

I.C.5. MINOS Detector Development

During the first half of 2000 the Argonne MINOS group devoted a substantial effort to completing the fabrication of scintillator-module assembly equipment for the prototype module production run in May. Most of the assembly machines and procedures had been substantially improved since the July 1999 prototype run. The successful May run validated the equipment design and manpower estimates prior to the setup of the first far-detector module-assembly factory at Caltech. In particular, Argonne engineers had made significant improvements to the glue machine, a semi-automatic device for gluing wavelength-shifting fibers into the grooves of scintillator strips. The machine, shown in Figure 1, now glues fibers into the strips for an entire module at once instead of one strip at a time. The group also built and commissioned the first module mapper, shown in Figure 2, which maps the response over the entire surface of a module with a radioactive source. The prototype run involved the participation of physicists, engineers and technicians from Caltech, the University of Minnesota, Fermilab and Argonne.

Following the May prototype run the scintillator group began the production of assembly equipment for the Caltech module factory, which is scheduled to begin production of MINOS far-detector modules in late summer. This included a glue machine, a module mapper, assembly and curing racks and a flycutter for polishing fiber optics connectors. After the Caltech factory is commissioned, the group will build similar equipment for a second far-detector factory at the University of Minnesota and for the near-detector module factory at Argonne.

During the first half of 2000 the Argonne electronics group worked on the specification, design and layout of the MASTER readout board, a complicated 9U VME module, for the MINOS near detector. They produced a document specifying the VME protocols for communicating with the board and began work on schematics and FPGA programming. The group also began the specification of communication protocols between the MASTER and the MINDER front-end crate and within the MINDER crate.

MINOS electronics engineers at Argonne and Fermilab worked together on several near-detector projects during the first half of the year. They produced specifications for the near-detector clock and its distribution system and also for the QIE front-end chip. A commercial fabricator produced prototype QIE chips from these specifications while work on a QIE-chip test setup began at Argonne and Fermilab.

Finally, the Argonne electronics group continued work on a number of Rabbit electronics readout systems for MINOS scintillator test setups at Argonne, Fermilab, Caltech, Minnesota and the University of Texas. These systems make use of existing Rabbit electronics cards and crates, which became available after the CDF upgrade at Fermilab. MINOS uses these systems for the module mapper readout, photomultiplier testing and for data acquisition from the 4-plane prototype. Several MINOS Rabbit systems have been brought into operation and are now in routine use.

(D. S. Ayres)

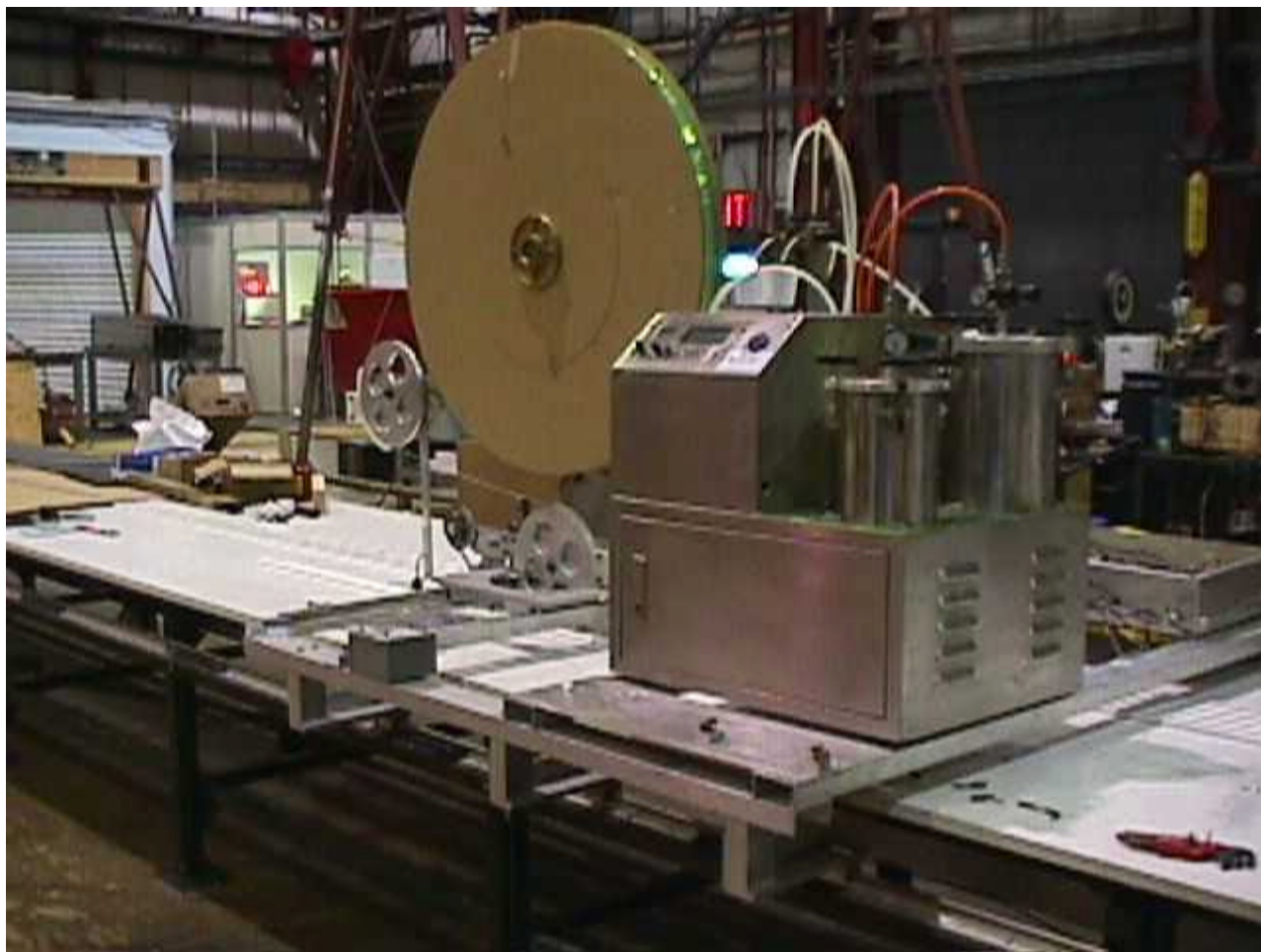


Figure 1. The MINOS glue machine. This device glues wavelength-shifting fibers into grooves in the 20 or 28 scintillator strips of MINOS detector modules and then covers them with reflective Mylar strips. The large metal box is the glue dispenser and the wavelength-shifting fiber is supplied from the large reel. The white reflective covering of the scintillator strips can be seen on the table under the glue machine carriage.



Figure 2. The MINOS module mapper. This device consists of a radioactive ^{60}Co source (inside the cylindrical shield near the center of the photo) attached to a movable carriage that can be positioned anywhere over the surface of a module. The photo shows one end of the aluminum light case of a module, including the fiber optics connections to the end manifold, on the table under the source.

(D. S. Ayres)

I.C.6. Electronics Support Group

CDF: We continued with our work in the development of front end electronics for the Shower Max Detector of the CDF Upgrade at Fermilab. For this project, we have overall responsibility for the electronics engineering of the system. The major responsibility in this project involves the coordination of the design engineering and system integration for the entire system, and overseeing the production of components. This development is a collaborative effort between Argonne and Fermilab.

Argonne is also responsible for the design, testing, and production of the ~6000 daughter boards that contain the SMQIEs, called SQUIDS. Each SQUID contains two SMQIEs, and also other support circuitry for calibration. The semi-final design was completed in this current period, and testing is in progress. Production is scheduled for Sept., 2000.

We are also responsible for the design, testing, and production of ~15,000 preamplifiers. These are used on the strip chambers in the Central Barrel of the detector to provide additional signal amplification. Two prototype design iterations were completed in this period, and testing is in progress. Production is scheduled to begin in the fall, 2000.

Another project that Argonne has direct design responsibility for is the design and production of a VME-based readout board, called the SMXR. This is a sophisticated data processor. It receives digitized data in floating-point form from the front end electronics at the rate of 300 MByte/Sec, adds together up to four words as sampled in time to reconstruct long signals from the detector spread out in time, and also forms trigger bits from the reconstructed signal. The data is stored in a buffer pending read-out by the data acquisition system. Testing of the final prototype was completed in this period, and production of ~100 modules is about to begin. Checkout is scheduled to begin in the summer.

Small system tests were performed at Argonne in this period. The tests were used to verify the robustness of the designs. Much of this effort required the generation of software, which was written by Argonne physicists. Argonne has the lead role in defining and executing the qualification testing of the prototypes as a prerequisite before production. Many of the system subcomponents were signed off in this period as a result of this testing effort.

ATLAS: We have major responsibilities in the development of electronics for the Level 2 Trigger of the ATLAS Detector at CERN. Working with colleagues from Michigan State University, we are responsible for the development of two parts of this system: The Level 2 Trigger Supervisor, and the Region of Interest (ROI) Builder.

The ROI Builder is the interface between the first level trigger and the second level trigger. When an event occurs in the detector, signals are sent from the front end electronics to the Level 1 Trigger. The Level 1 Trigger collects event fragments from all over the detector, and stores them in a buffer. The Level 1 Trigger boards then send lists of addresses to the ROI Builder, identifying where the event data from the "Region of Interest," can be found. The ROI Builder collects the addresses for the event, and "builds" the event. It then sends the result to the Trigger Supervisor for distribution to Level 2 processors. The board is highly complex, using fast, high-density Field programmable Gate Arrays (FPGAs) to implement the functionality.

In this period, testing continued on the prototype system. The initial testing of system subcomponents was done at Saclay. The system was later moved to CERN, where the components were merged to form a larger system. Tests are presently underway. Argonne is providing much of the software development and support for this phase of the project.

MINOS: We continued our involvement with MINOS, the Neutrino Oscillation Experiment at Fermilab and the Soudan mine. Our group has Level 3 Management responsibility for the front end electronics of the experiment, as well as responsibility for a large portion of the front end design.

In the fall of 1999, we began the development of the read-out system for the Near detector, located at Fermilab. The QIE, a custom integrated circuit developed at Fermilab, was chosen as the front end device for the instrumentation. The QIE digitizes continuously at 53 MHz. The operations are pipelined so that there is no deadtime due to digitization. The digitized data will be stored in a local memory during the entire period of the spill. The data will be sent from the local memory to a VME read-out board after the spill is over. In between spills, the electronics will record data from cosmic rays. A signal from the dynode of the photomultiplier will cause the data from several clock cycles to be stored in the local memory when operating in this mode. The QIEs and associated circuitry will be built on small daughter boards resembling memory SIMMs, using surface mount parts. The VME read-out board will be a redesign of the SMXR designed for CDF (see above.) The new board, called the MASTER Module, will contain a high level of programmable logic.

The chip design, and the development of the QIE daughter board, are responsibilities of Fermilab. Argonne will design the VME read-out board, and also the mother boards that host the QIE daughter boards. We also have overall responsibility for the design of the rest of the system for the Near Detector, including the specifications for the QIE performance.

We had previously completed writing specifications for changes to the QIE design. Fermilab engineers completed the changes, and the device was submitted for fabrication in February. We received the devices from the foundry in June, and testing has begun at Fermilab. We plan to complete the testing by the fall, and prepare for small system tests.

We also began the design of the MASTER Module. The schematic capture is almost done, and the board design will begin in July. We plan to fabricate the prototype board by late summer, and begin testing in early fall.

ZEUS: Work continued at the ZEUS experiment at DESY to replace the tracking detector in the forward region during the shut down in 2000. The new detector will use straw tubes, rather than the older-style wire chamber technology. The detector produces a pulse in response to a charged particle passing through the detector. The electronics must sense the pulse, and send a digital signal to the “back end” electronics in response, where a timestamp for the signal is recorded. This is then used to reconstruct the trajectory of the particle through the tracking detector.

We are planning to use a custom integrated circuit designed at RENN, called the ASDQ. The chip was designed for use with the tracking detector in the CDF experiment, and performs the front end analog signal processing. Design work is in progress to develop a read-

out board that hosts this device. We plan to develop this board by the summer, and deliver it to DESY for testing. Production of 150 boards to service 12,000 detector channels is scheduled to begin in the fall.

(G. Drake)

II. THEORETICAL PHYSICS PROGRAM

II.A. THEORY

II.A.1 Associated Production of Gauginos and Gluinos or Squarks at Hadron Colliders in Next-to-Leading Order SUSY-QCD

Edmond Berger, Tim Tait, Michael Klasen (Hamburg) completed an *ab initio* calculation through next-to-leading order in perturbation theory of the expected cross section for the *associated production* of a strongly interacting gluino along with a chargino or a neutralino, states that experience only the weak and electromagnetic interactions. They issued a major paper in May 2000, since published Physical Review **D62**, 095014 (2000). The paper, 91 pages in length, includes detailed technical appendices that provide a thorough explanation of their approach. The work by Berger, Klasen, and Tait is the first next-to-leading order (NLO) calculation of the production of gaugino-like charginos and neutralinos in association with gluinos at hadron colliders, including the strong corrections from colored sparticles and particles in loops, and three-particle final states involving the emission of light partons. Majorana fermions and extra singularities related to on-shell final-state sparticles were important technical challenges in the calculation. In the course of computing the virtual contributions, they encountered new divergent four-point functions. The contributions from real emission of light particles were treated with a phase space slicing method. They predicted inclusive cross sections at the Fermilab Tevatron and CERN LHC. The NLO cross sections are more stable against variations in the hard-scattering scale parameter and are greater than the leading-order values.

The search for sparticles is a principal motivation of the forthcoming Run II of the Fermilab Tevatron collider and of the CERN Large Hadron Collider (LHC) program. In popular models of SUSY breaking, such as the supergravity (SUGRA) and gauge-mediated models, the mass spectrum favors much lighter masses for the low-lying neutralinos and charginos than for the squarks and gluinos. This mass hierarchy means that the phase space for production of neutralinos and charginos and the corresponding partonic luminosities will be greater than those for gluinos and squarks. These advantages are potentially decisive at a collider with limited energy, such as the Tevatron. Furthermore, associated production has a clean experimental signature. For example, the lowest lying neutralino is the (stable) lightest supersymmetric particle (LSP) in SUGRA models, manifest as missing energy in the events, and it is the second lightest in gauge-mediated models. Berger, Klasen, and Tait have received many invitations to present major conference talks and seminars on their work. Berger spoke at SUSY2K at CERN in June 2000, the International Conference on High Energy Physics in Osaka, and at RADCOR2000.

(E. L. Berger)

II.A.2 Massive Lepton-Pair Production and the Gluon Density

Edmond Berger, Lionel Gordon, and Michael Klasen proposed and developed a novel idea to extract valuable information on the gluon parton density from data on lepton-pair production in hadron reactions at large transverse momentum, but relatively small values of mass of the pair. Their first paper was published in Phys. Rev. **D58**, 074012 (1998). In Phys. Rev. **D62**, 014014 (2000), they extend their investigations to the spin-dependent situation that may be examined at Brookhaven's RHIC facility and elsewhere. Several sequels containing additional research appeared as Argonne reports ANL-HEP-CP-00-001 (hep-ph/0001190), ANL-HEP-CP-00-002 (hep-ph/0001127), ANL-HEP-CP-00-009 (hep-ph/0003211), and ANL-HEP-CP-00-098 (hep-ph/0009257). These papers will appear in the proceedings of various conferences at which the work was presented. The basic idea is a simple one, but it has been heretofore overlooked. The papers by Berger, Gordon, and Klasen are the first to recognize that lepton-pair data should be an excellent new source of information on the gluon density at both fixed-target and collider energies. They also point out advantages of low mass lepton-pair production vis-à-vis real hard photon production. There is no non-perturbative fragmentation contribution in lepton pair production so the interpretation is cleaner. In addition, there is no need to isolate the lepton-pair so that theoretical infrared uncertainties associated with isolation are eliminated. There is a wealth of Drell-Yan events in the Fermilab hadron collider data sample and at fixed-target energies that can be exploited to advantage to determine useful information on the gluon density.

(E. L. Berger)

II.A.3 Physics Opportunities at the Fermilab Tevatron and the LHC

Edmond Berger was a Theory Convener of the Working Group on Photon and Weak Boson Production as part of the 1999 year-long "Workshop on Physics at Run II at the Fermilab Tevatron: QCD and Weak Boson Physics" and a participant in the 1999 CERN Workshop on Standard Model Physics at the LHC. The lengthy report of the Working Group on Photon and Weak Boson Production group is available as hep-ph/0005226. Along with Tim Tait, Berger studied the pair mass dependence near threshold of top quark pair production as a means to measure the *spin* of the top quark in events from hadron collisions. As a byproduct, they discuss the possibility that a top squark signal could be hidden in the sample of events associated with the top quark. Their paper, ANL-HEP-CP-00-014 (hep-ph/0002305), was contributed to the Thinkshop on Top-Quark Physics for the Tevatron Run II, Fermilab, and is included in the chapter **Top Quark Physics** that appears in the Report of the "1999 CERN Workshop on SM physics (and more) at the LHC", Geneva, October, 1999 (hep-ph/0003033). Along with Brian Harris and Zack Sullivan, Berger studied single top squark production via a baryon-number violating (R-parity violating) coupling and made predictions for cross sections and signatures of this process for Run II of the Tevatron. Their paper, ANL-HEP-CP-99-40, is included in the chapter **Searching for R-Parity Violation at Run-II of the Tevatron** (hep-ph/9906224) to appear in "Physics at Run II Workshop: Supersymmetry/Higgs". Working with Michael Klasen,

Berger studied lepton-pair production (the Drell-Yan process) at both the Tevatron and the LHC with a view towards further constraining the gluon parton density in the proton. Their contributions, ANL-HEP-CP-00-002 (hep-ph/0001127) and ANL-HEP-CP-00-009 (hep-ph/0003211), are included in the chapter **QCD** in the Report of the “1999 CERN Workshop on SM physics (and more) at the LHC”, Geneva, October, 1999 (hep-ph/0005025) and in the summary report of the working group on parton densities of the “Workshop on Physics at Run II at the Fermilab Tevatron: QCD and Weak Boson Physics”.

(E. L. Berger)

II.A.4 Argonne 2000 Theory Institute on Supersymmetry and Higgs Physics

The Argonne 2000 Theory Institute on Supersymmetry and Higgs Physics took place over the three-week period April 25 – May 12. Edmond Berger, Gordon Chalmers, Brian Harris, David Kaplan, Zack Sullivan, Tim Tait, and Carlos Wagner organized it with the indispensable assistance of theory secretary Sandy Gotlund. The goal was to examine outstanding issues in theory and phenomenology and the impact of recent theoretical ideas on Higgs and supersymmetry particle searches at the CERN LEP collider, the Fermilab Tevatron, and the LHC. Three talks were scheduled per day. Intense informal discussion was facilitated and encouraged among external participants and Argonne physicists by the way the program was structured and by efforts to provide office space and computer access within the High Energy Physics building for all participants. The topics explored extended beyond the theory and phenomenology of Higgs and SUSY particle production and observation to include R-parity violation, CP-violation, extra-space-time dimensions, rare B decays, dark matter, and neutrino masses and mixing. Forty-six external theorists participated as well as a few experimenters from Fermilab. The Theory Institute was open to participation by all in the Division and elsewhere. Collaborations were originated, and the enthusiastic responses of participants included many suggestions for a return engagement in 2001. Associate Laboratory Director Frank Fradin provided funding through a Theory Institute grant of \$20K. Proceedings were published electronically as <http://gate.hep.anl.gov/kaplan/sched.html>.

(E. L. Berger)

II.A.5 Resummation of Large Corrections to Heavy-Quarkonium Decays

A previous report (January 1, 1999 – June 30, 1999) described a calculation by G. Bodwin and Y.-Q. Chen (ITP, Beijing) of a resummation of large corrections to the ratio of heavy-quarkonium decay rates $R = G(\mathbf{h}_c \rightarrow \text{light hadrons})/G(\mathbf{h}_c \rightarrow g\bar{g})$. The one-loop correction to R is large ($\approx 14.5\mathbf{a_s/p}$), and the decay rate through one-loop is very sensitive to the choice of the renormalization scale. In their previous work, Bodwin and Chen noticed that most of the large one-loop correction is proportional to \mathbf{b}_0 . That is, it comes from vacuum-polarization corrections to the final-state gluon propagators in the process $\mathbf{h}_c \rightarrow \text{light hadrons}$. Motivated by

this observation, they carried out an all-orders resummation of the vacuum-polarization corrections. Their result is much less sensitive to the renormalization scale than the one-loop result. Consequently, one can make a meaningful comparison with experiment. The agreement of their result with experiment is good, in contrast with the result that one obtains by using Brodsky-Lepage-Mackenzie (BLM) scale setting, which overshoots experiment by a factor of five.

In carrying out this initial analysis, Bodwin and Chen generally summed vacuum-polarization corrections before carrying out the final-state phase-space integrations. Recently, they discovered that, not only does one obtain a different result by carrying out these operations in the opposite order, in some instances one obtains an infinite result when one integrates first and then sums the perturbation series. In these instances, the series of integrated terms grows as the factorial of the order. This is the characteristic signal for the presence of a renormalon—a singularity in the Borel transform of the perturbation series that appears when one tries to incorporate long-distance, nonperturbative physics.

Bodwin and Chen found that they can remove such long-distance effects from the phase-space integrals by absorbing them into Nonrelativistic QCD (NRQCD) matrix elements of four-fermion operators. It is crucial in identifying the long-distance contributions to recognize that there are no contributions in which both final-state gluons have small virtualities. Bodwin and Chen were able to demonstrate this by deforming the contours of integration for the virtualities of the final-state gluons into the complex plane, out of the regions in which both gluon virtualities are small. The contour-deformation argument is related to the fact that the emission of two low-virtuality, high-energy gluons can occur causally in the decay only if the gluons are created in a localized (short-distance) space-time region.

Once the long-distance contributions have been removed from the phase-space integrals, one is justified in summing the perturbation series, which converges, albeit very slowly. In contrast, the procedure of summing the series before carrying out the phase-space integration is not justified because the unintegrated series diverges for low gluon virtualities.

In order to circumvent the slow convergence of the perturbation series of phase-space-integrated contributions, Bodwin and Chen expressed its sum in terms of the quantity that one obtains by summing the vacuum-polarization series first and then integrating over phase space. This last quantity is relatively easy to compute. By making use of contour deformation arguments, Bodwin and Chen were able to relate the difference between these quantities to residues at the gluon Landau poles, which are easily computed by numerical methods.

The value of R that emerges from this new analysis differs only slightly from the value that Bodwin and Chen had obtained previously. (Uncertainties arising from the unknown nonperturbative NRQCD matrix element are estimated to be small.) However, the new approach places the calculation on a much sounder theoretical footing and opens the door for applications of the technique to other QCD processes.

A paper describing this work (ANL-HEP-PR-00-109) is in preparation.

(G. T. Bodwin)

II.A.6 Computational Physics

For several years, we have been performing finite temperature simulations of lattice QCD using a lattice action modified by the addition of an irrelevant four-fermion interaction, which allows us to perform simulations at zero quark mass. Such zero mass simulations allow the extraction of the critical exponents at the transition from hadronic matter to a quark-gluon plasma, and will eventually yield the equation of state for same. We completed the simulations on lattices with time extent 6 during this 6-month period and discovered that the critical indices differed significantly from those expected from universality arguments. Instead they were consistent with those for a tricritical point (see Fig. 1). Because we had previously observed a first-order transition for lattices of time extent 4, and a tricritical point is the point that separates a line of first-order transitions from a line of universal second-order transitions, this should not have been totally unexpected. What it suggests is that this non-universal behavior is a lattice artifact, and that true universal behavior would obtain for lattices of temporal extent ≥ 8 . Our observations explain why others, using the standard staggered fermion action, had been unable to observe the scaling behavior they expected. We expect to perform simulations on lattices with time extent 8 in the near future. To date these simulations have used the CRAY SV1's and the CRAY T3E at NERSC.

Because the Euclidean-time fermion determinant for QCD with a finite chemical potential for quark (baryon) number is complex, standard simulation methods fail. Such studies would give one information on the phase structure of nuclear matter as the baryon number density is varied. We are thus studying a simpler field theory, two-color QCD, which *can* be simulated at finite chemical potential. This model exhibits the formation of a diquark condensate for large enough chemical potentials, a property some have suggested of real QCD. We are performing simulations on an 8^4 lattice to measure the chiral and diquark condensates on the CRAY SV1's at NERSC and the IBM SP at NPACI. We are also performing simulations on a $12^3 \times 24$ lattice on the IBM SP at NERSC, measuring the spectrum of Goldstone bosons associated with these spontaneous symmetry breakings in addition to those order parameters measured on the smaller lattice.

The major problem with representing fermions on the lattice is the lack of exact (flavor) chiral symmetry. Domain-wall fermions allow a systematic approach to truly chiral fermions. True chirality is only obtained in the limit that the extent of the fictitious fifth dimension associated with the domain wall approach becomes infinite. What is needed are studies of how close one can get to chiral symmetry on a finite lattice. We have been performing such studies on quenched lattice configurations at high temperature where the behavior is expected to be simpler than at zero temperature. These studies involve testing the extent to which the Atiyah-

Singer index theorem is obeyed as a function of the length on the lattice in the fifth dimension, and examining the chiral properties of the scalar/pseudoscalar mesons. These measurements are being performed on the CRAY SV1's at NERSC.

(D. K. Sinclair)

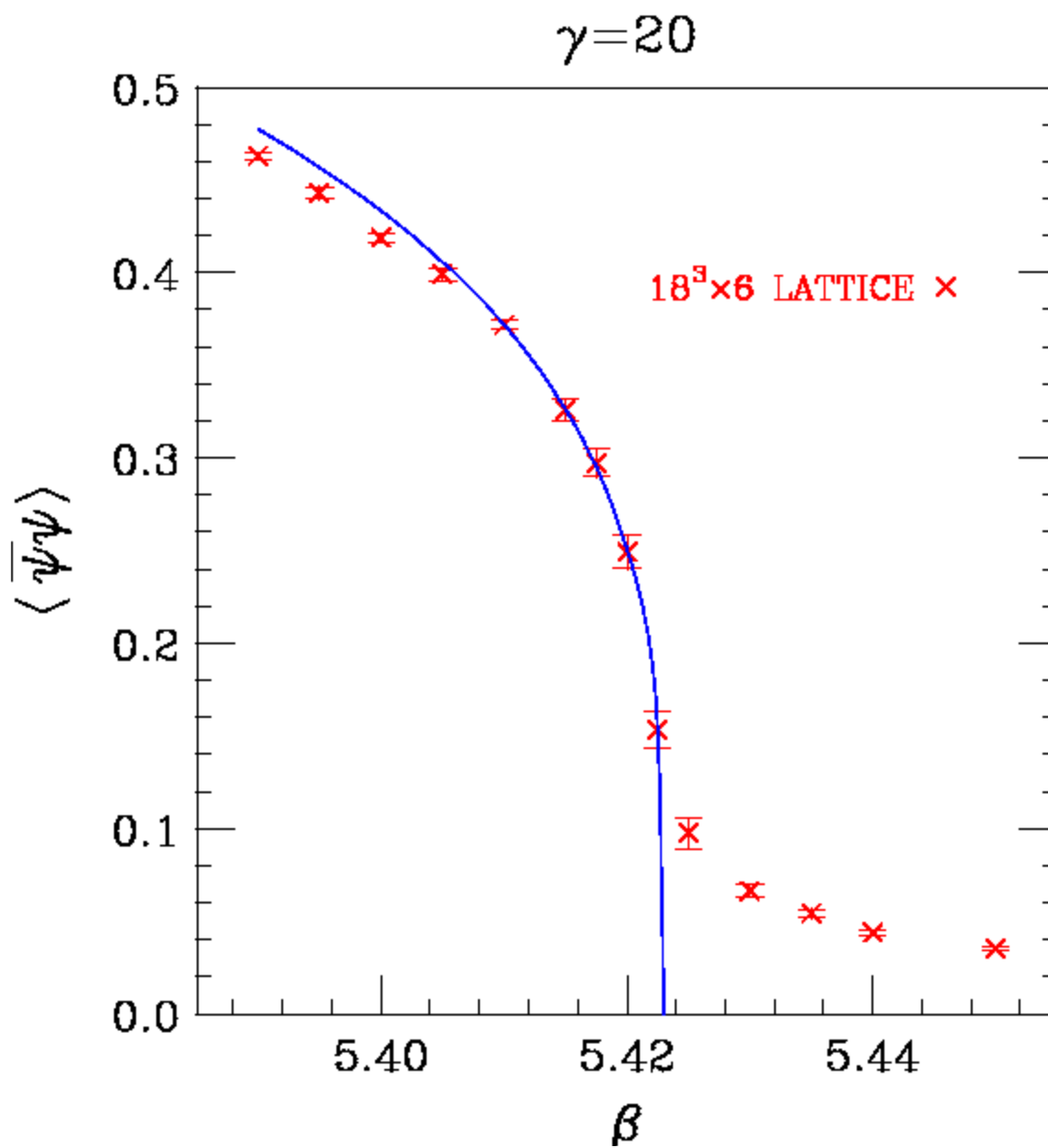


Figure 1. Temperature dependence of the chiral condensate near the chiral phase transition. The solid curve represents a fit to the expected scaling behavior.

II.A.7 The tW Mode of Single Top Production

Tim Tait has examined the production of single top quarks through an associated mechanism whereby a W boson and top quark are produced as a pair. Published in Phys. Rev. **D61**:034001 (2000), the article dealt with a theoretical subtlety associated with classifying the higher order QCD corrections to the leading order process as belonging to single top production or to purely strong production of a pair of top quarks, followed by one top decaying weakly. The signal and major backgrounds were studied in the context of the proposed CERN LHC collider, and it was demonstrated that even with a much smaller data sample than the one expected, the signal may be precisely determined. This process is invaluable as a direct test of the weak interactions of the top quark.

(T.M.P. Tait)

II.A.8 New Top-Flavor Models With Seesaw Mechanism

With Hong-Jian He and C.-P. Yuan (Michigan State University), Tim Tait has constructed a new set of models by which the electroweak symmetry is broken dynamically, and a large top mass is naturally realized. This work, published in Phys. Rev. **D62**:011702 (2000), introduces additional electroweak interactions for the third family quarks and, results in a rich array of collider signatures ranging from direct production of heavy exotic gauge bosons, to additional weak doublet quarks. These processes could be observed at the upcoming runs of the Fermilab Tevatron and CERN LHC colliders. Constraints from low-energy measurements were also considered and it was found that a large range of viable parameter space remains after imposing those constraints.

(T.M.P. Tait)

II.A.9 Supersymmetry Breaking, Fermion Masses and a Small Extra Dimension

In an article published in JHEP 0006:020 (2000), David Kaplan and Tim Tait have constructed a class of supersymmetric models in which the observed quark flavor structure, including quark masses and CKM mixing elements, are realized by the existence of a small extra dimension. The quarks and Higgs bosons are localized at different points in the extra dimension, and the overlap of their localized wave functions generates the wide range of quark masses from a theory in which all dimensionless couplings are order 1 and the dimensionful couplings are of order the Planck mass. Supersymmetry breaking by gaugino mediation was also considered and, it was found that the flavor structure in the fermions leaves a distinct imprint on the masses of their super-partners, allowing one to distinguish this mechanism of flavor and supersymmetry breaking from other models in the literature.

(T.M.P. Tait)

II.A.10 Single Top Quark Production as a Window to Physics Beyond the Standard Model

Tim Tait and C.-P. Yuan (Michigan State University) have considered both model-independent and specific models of new physics and, their impact on single top production at either the Fermilab Tevatron or the CERN LHC. Published in Phys. Rev. **D63**:014018 (2001),

this work explains how one may use the various sources of information about the weak interactions of the top quark, including the W -gluon fusion and W^* processes of single top production and, the top decay into a W boson and bottom quark, to untangle the structure of the top's weak interactions. One important conclusion drawn is that the various processes commonly called single top production are actually sensitive to quite different types of physics and, thus, should be measured independently in order to extract the maximum information about the top quark.

(T.M.P. Tait)

II.A.11 The Anomaly and Reggeon Field Theory in QCD

Alan White is pursuing an extended program, the goal of which is to find a candidate regge region S -Matrix for QCD starting from perturbative reggeon diagrams containing reggeized gluons and quarks. Both hadrons and the pomeron are looked for as reggeon bound-states in multi-regge amplitudes. Motivation and a means of analysis are provided by White's past work on supercritical reggeon field theory. The central idea is that, in the multi-regge region, the $U(1)$ and chiral flavor anomalies can provide the necessary "non-perturbative" properties of confinement and chiral-symmetry breaking. White was invited to describe his program at two International Symposia, the Gribov-70 Symposium held in Paris, France, honoring what would have been Vlodya Gribov's 70th birthday and, the Symposium on Evolution Equations and Large Order Estimates in QCD held in St. Petersburg, Russia, honoring the 60th birthday of Lev Lipatov.

A long paper that has been submitted to *Physical Review*, is an expanded and revised version of the paper originally submitted to the Los Alamos archive as hep-ph/9910458. In this paper it is shown that the anomaly appears in the triple-regge limit, in the reggeon interactions due to diagrams containing a single quark loop. All the reggeon interactions generated by diagrams of this kind contain a triangle diagram. The effective vertices involve products of γ -matrices that (in some cases) give $\gamma_5 \gamma_\mu$ couplings that can produce the anomaly. Even at lowest-order, many diagrams potentially contribute to the anomaly and an asymptotic dispersion relation formalism has to be used to systematically count all contributions. There are many cancellations and the anomaly remains only in special circumstances. It does not appear in the scattering of elementary quarks or gluons but can appear in the scattering of bound states. It is anticipated that it will play a crucial role in determining the properties of a bound state S -Matrix and, in particular, in determining that the pomeron is described by reggeon field theory.

(A. R. White)

II.A.12 Contributions to the Encyclopedia on Supersymmetry

C. Zachos has contributed ten compact technical essay entries to the *Concise Encyclopedia on Supersymmetry and Noncommutative Structures in Mathematics and Physics*, edited by J. Bagger, S. Duplij, and W. Siegel (Kluwer Academic Publishers, Dordrecht) in press.

The contributions are on the following subjects: Fermionic Center; Graviphoton; Moyal Algebra, Supersymmetrization; Presentation for Supervirasoro Algebras; Krichever-Novikov Algebra, Supersymmetrization; Non-local Charges in Supersymmetric Sigma Models; Nonabelian Duality for SUSY Sigma Models; Wess-Zumino-Witten-Novikov Model, Supersymmetrization; Effective Lagrangians for Broken Supersymmetry; Star Product.

(C. Zachos)

III.A.2 Experimental Program

a. Two-Beam Acceleration Experiment

We have made a major breakthrough during this period: Demonstration of the proof of principle experiment for the dielectric step-up transformer. The experiment uses the newly configured AWA witness beam line. The experimental setup is shown in Figure 2.

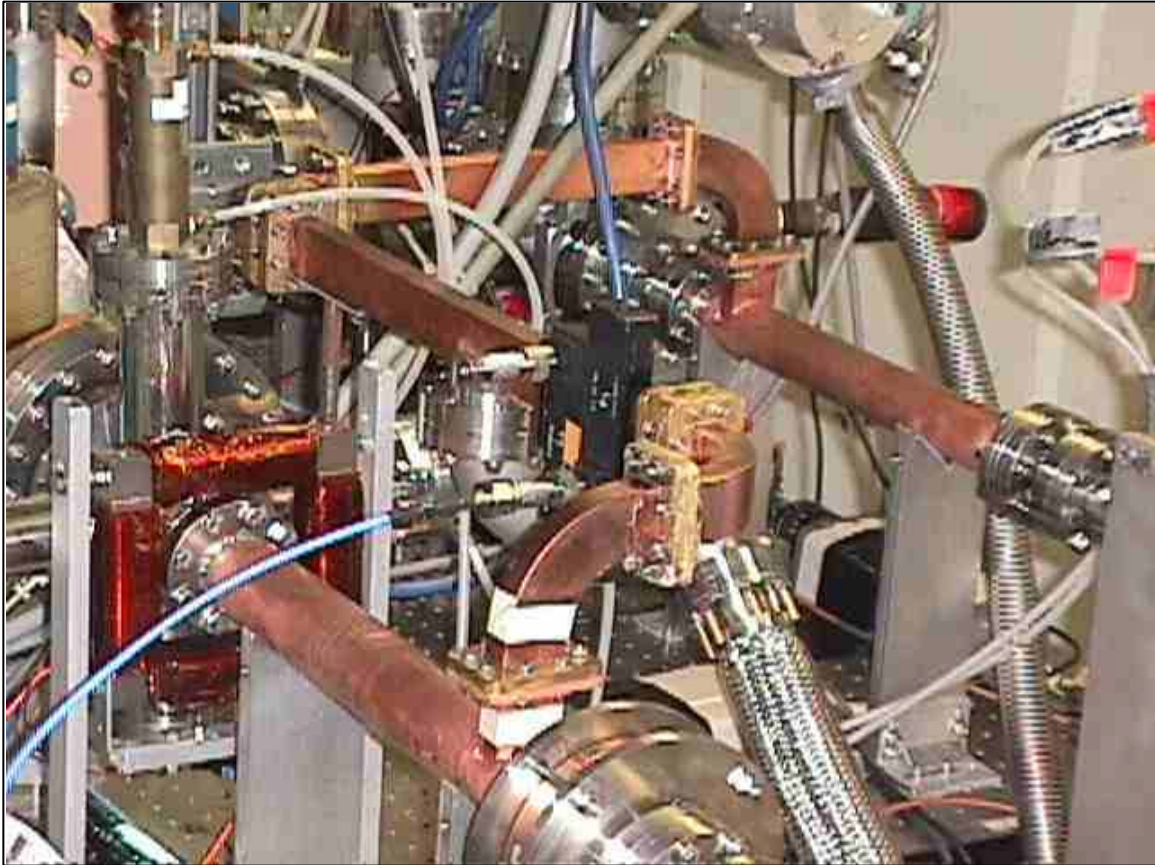


Figure 2. Experimental setup for the two-beam acceleration experiment.

In Figure 2, the stage 1 and stage 2 dielectric tubes were connected through a rectangular waveguide. The wakefield generated in stage 1, which has lower dielectric constant and smaller dimension, is coupled to the stage 2 tube to achieve higher acceleration gradient in it. The preliminary result is shown in the Figure 3.

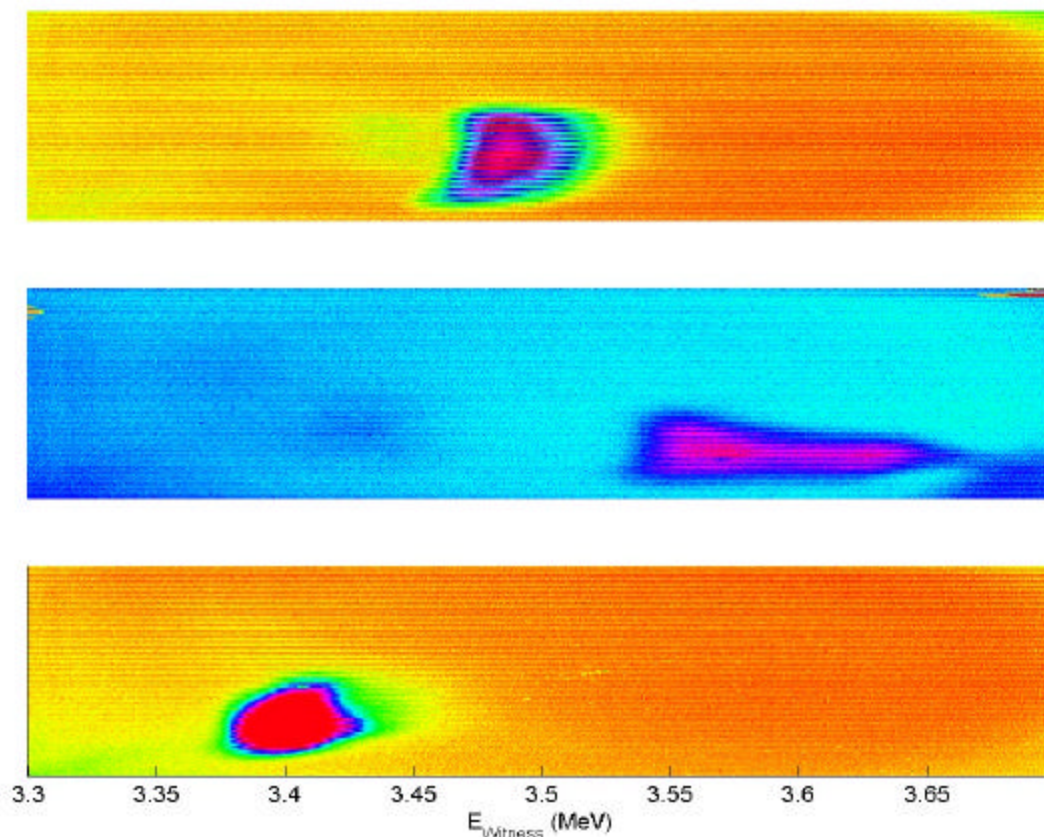


Figure 3. Images of the witness beam at the witness spectrometer focal plane:
Top: Drive beam off;
Center: Delay = 58 ps (accelerating phase;
Bottom: Delay = 8 ps (decelerating phase).
The accelerating structure is a two-beam device operating at 7.8 GHz.
The transformer ratio is 2.5, and the accelerating gradient is 7 MeV/m.

In Figure 3, we showed that a low-charge witness beam is accelerated in the much higher field of stage 2 than in the deceleration field of stage 1 (> 4 times). Further experiment exploring the detailed wakefields shape and timing is underway.

b. Traveling Wave 11.4 GHz X-Band Accelerator

Work continued on the traveling wave dielectric structure development. The structure was fabricated and tested in the laboratory with satisfactory results. Numerical simulation indicates that efficient RF coupling to the desired TM_{01} can be achieved as shown in Figure 4. High power test of this structure is going to be proceeded either at SLAC or NRL in the near future.

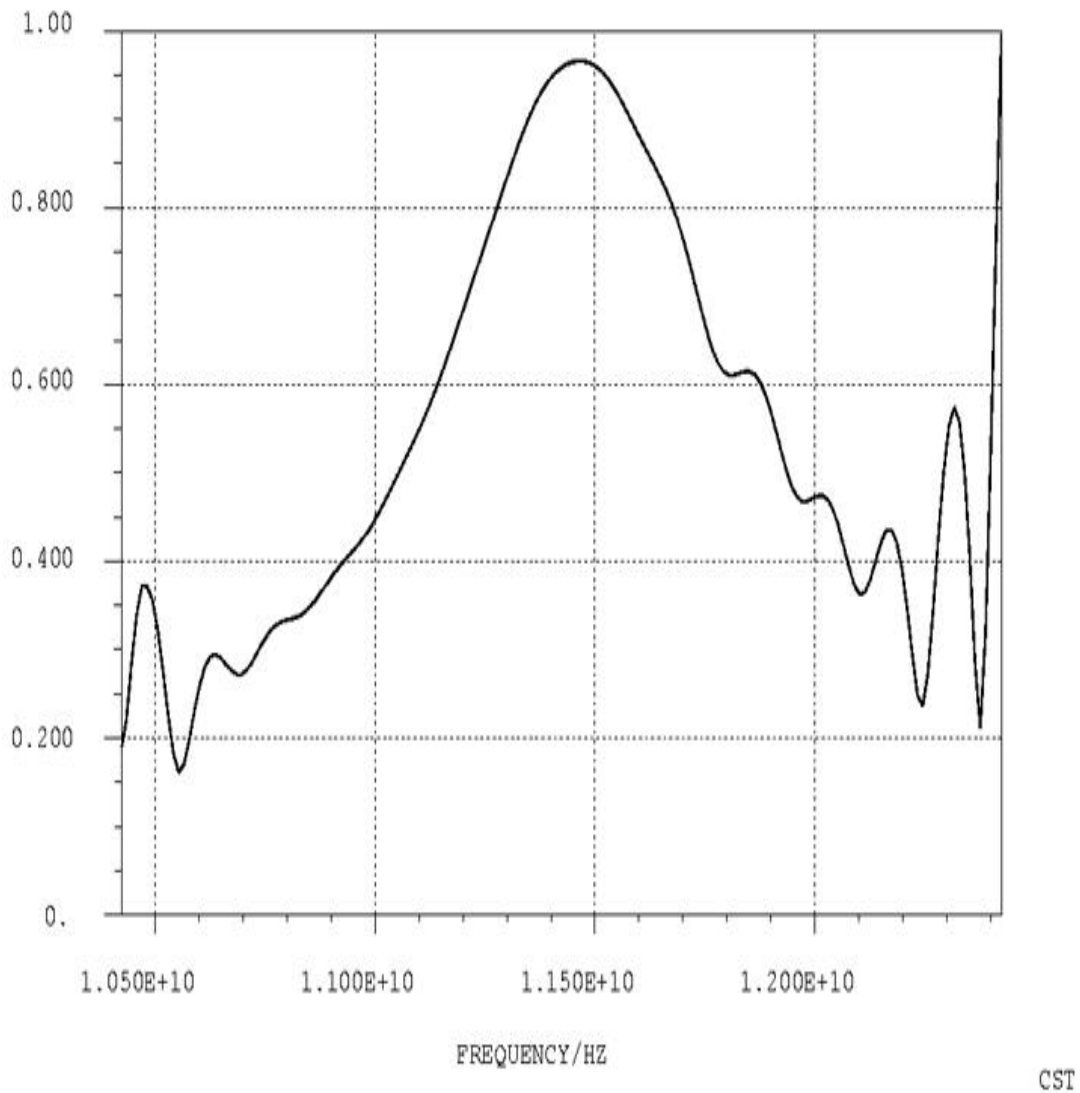


Figure 4. Calculated RF transmission coefficient from rectangular waveguide to dielectric tube. The numerical simulation results agrees very well with the experimental data.

c. Theoretical Accelerator Physics

We explored a new method of wakefield acceleration: Ramped bunch train (RBT). The concept uses a train of ramped electron bunch train (linearly ramped) to enhance the transformer ratio. Our simulations show that transformer ratio > 7 can be achieved using AWA beam. Design of an experiment is underway for proof of principle experiment.

(W. Gai)

III.B. MUON COLLIDER R&D

III.B.1 Muon Cooling Experiment

a. Dark Current Electrons and X-Rays

A measurement of dark current electrons and x-rays from a rf cavity using the absorber method was finished. Al Moretti, and Milorad Popovic of Fermilab helped to measure a roughly isotropic x-ray flux around the Taiwan gun in building 366. This x-ray flux is roughly consistent with calculations done with EGS4, which give a more accurate picture of the behavior of low energy x-rays in materials. The results of this experiment, though very rough, were used to deduce the initial dark current flux, and this flux was consistent with other measurements. The conclusions have been very influential, since they argued that all the instrumentation we were planning to use for our muon cooling demonstration experiment would not have worked, thus necessitating a complete redesign of the experiment. The x-ray measurements will be continued on a 6 cell cavity operating at 805 MHz which is being completed in Lab "G" of Fermilab as part of the Muon Cooling effort.

b. Measuring Muon Cooling with Bunched Beams

The development of an experiment to demonstrate muon cooling with bunched muon beams has been a high priority effort. All aspects of a bunched beam experiment were considered in a preliminary way, including muon production, backgrounds, instrumentation, required precision and costs. The primary argument seemed to be that the instrumentation must have a very fast response time and large dynamic range to operate in the presence of large backgrounds, two criteria easily met by Faraday cups and SEMs, which are not usually used for these features. Measurements, at the ANL/CHM linac, of response times on the order of 150 ps for Faraday cups indicate that these techniques should be useful. Among the more peripheral details are the development of some cost algorithms for the muon cooling experiment and suggestions on how the cost can be minimized.

(J. Norem)

IV. PUBLICATIONS

IV.A. BOOKS, JOURNALS, AND CONFERENCE PROCEEDINGS

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J. Breitweg, S. Chekanov, M. Derrick, D. Krakauer, S. Magill, B. Musgrave,
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PDK-730

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J. Breitweg, S. Chekanov, M. Derrick, D. Krakauer, S. Magill, B. Musgrave,
A. Pellegrino, J. Repond, R. Stanek, R. Yoshida, and the *ZEUS Collaboration*
Phys. Lett. **B471**: 411 (2000)

Wakefield Excitation in Multimode Structures by a Train of Electron Bunches

J. G. Power, M. E. Conde, W. Gai, R. Konecny, and P. Schoessow
Proceedings of the 1999 IEEE Particle Accelerator Conference (PAC'99), Vol. **5**,
edited by A. Luccio and W. MacKay (IEEE, New York, 2000), p. 3621.

IV.B. MAJOR ARTICLES SUBMITTED FOR PUBLICATION

A Search for Resonance Decays to \bar{n} -Jet in e^+p Scattering at HERA

J. Breitweg, S. Chekanov, M. Derrick, D. Krakauer, S. Magill, B. Musgrave,
A. Pellegrino, J. Repond, R. Stanek, R. Yoshida, and the *ZEUS Collaboration*
Physical Review D
ANL-HEP-PR-00-121

Angular Dependence of the pp Elastic Scattering Spin Correlation Parameter A_{oonn} Between 0.8 and 2.8 GeV. I. Results for 1.80 - 2.24 GeV.

C. E. Allgower, M. E. Beddo, D. P. Grosnick, T. E. Kasprzyk, D. Lopiano, and
H. M. Spinka, *et al.*
Physical Review C
ANL-HEP-PR-00-81

Design and Simulation of a High-Frequency High-Power RF Extraction Device Using a Dielectric-Loaded Waveguide

W. Gai and P. Schoessow

Nucl. Inst. & Meth. in Phys. Research A: Accelerators, Spectrometers, Detectors and Associated Equipment, accepted.

ANL-HEP-PR-00-48

Dijet Production by Double Pomeron Exchange at the Fermilab Tevatron

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF Collaboration*

Physical Review Letters

ANL-HEP-PR-00-78

Direct Measurement of the W Boson Width in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF Collaboration*

Physical Review Letters

ANL-HEP-PR-00-79

Dual Expansions of $N = 4$ Super Yang-Mills Theory via IIB Superstring Theory

G. Chalmers and J. Erdmenger

Nuclear Physics B

ANL-HEP-PR-00-55

Limits on Gravitino Production and New Processes with Large Missing Transverse Energy in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman, J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF Collaboration*

Physical Review Letters, accepted

ANL-HEP-PR-00-73

Making Physics: A Biography of Brookhaven National Laboratory, 1946 - 1972

P. Schoessow

Endeavour, accepted

ANL-HEP-PR-00-13

Measurement of Dijet Cross Sections for Events with a Leading Neutron in Photoproduction at HERA

J. Breitweg, S. Chekanov, M. Derrick, D. Krakauer, S. Magill, B. Musgrave, A. Pellegrino, J. Repond, R. Stanek, R. Yoshida, and the *ZEUS Collaboration*

Nuclear Physics B, accepted

ANL-HEP-PR-00-122

Measurement of $d\mathbf{s}/dy$ for High Mass Drell-Yan e^+e^- Pairs from $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman,
J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF*
Collaboration

Physical Review Letters
ANL-HEP-PR-00-80

Measurement of Inclusive D_s^\pm Photoproduction at HERA

J. Breitweg, S. Chekanov, M. Derrick, D. Krakauer, S. Magill, B. Musgrave,
A. Pellegrino, J. Repond, R. Stanek, R. Yoshida, and the *ZEUS Collaboration*
Physics Letters B, accepted
ANL-HEP-PR-00-32

Measurement of J/ψ and $\psi(2S)$ Polarization in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman,
J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF*
Collaboration

Physical Review Letters
ANL-HEP-PR-00-76

Measurement of $p^0 p^0$ Production in Nuclear Matter by p^- at 0.408 GeV/c

C. E. Allgower and H. Spinka, and the *Crystal Ball Collaboration*
Physical Review Letters
ANL-HEP-PR-00-59

Measurement of the Proton Structure Function F_2 at Very Low Q^2 at HERA

J. Breitweg, S. Chekanov, M. Derrick, D. Krakauer, S. Magill, B. Musgrave,
A. Pellegrino, J. Repond, R. Stanek, R. Yoshida, and the *ZEUS Collaboration*
Physics Letters B
ANL-HEP-PR-00-56

Measurement of the Top Quark Mass with the Collider Detector at Fermilab

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman,
J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF*
Collaboration

Physical Review D
ANL-HEP-PR-00-84

Measurement of the Top Quark p_T Distribution

R. E. Blair, K.L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman,
J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF*
Collaboration

Physical Review Letters
ANL-HEP-PR-00-77

Next-to-Leading Order SUSY-QCD Predictions for Associated Production of Gauginos
and Gluinos

E. L. Berger, M. Klasen, and T.M.P. Tait
Physical Review D
ANL-HEP-PR-00-45

Observation of Orbitally Excited B Mesons in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman,
J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF*
Collaboration

Physical Review D
ANL-HEP-PR-00-68

QCD

E. L. Berger, S. Alekhin, P. Aurenche, C. Balazs, R. D. Ball, G. Battistoni *et al.*
Proceedings of the Workshop on Standard Model Physics (and more) at the LHC,
Geneva, Switzerland, October 14-15, 1999.
ANL-HEP-PR-00-50

Radio-Frequency Measurements of Coherent Transition and Cherenkov Radiation:
Implications for High-Energy Neutrino Detection

P. Gorham, D. Saltzberg, P. Schoessow, W. Gai, J. G. Power, R. Konecny, and
M. E. Conde
Physical Review E
ANL-HEP-PR-00-124

Renormalization-Group-Improved Effective Potential for the MSSM Higgs Sector with Explicit
CP Violation

M. Carena, J. Ellis, A. Pilaftsis, and C.E.M. Wagner
Nuclear Physics B
ANL-HEP-PR-00-30

Report of the Parton Distributions Working Group

E. L. Berger, S. T. Kuhlmann, *et al.*
Proceedings of the Workshop on Physics at Run II at the Fermilab Tevatron:
QCD and Weak Boson Physics, Batavia, IL, November 4-6, 1999.
ANL-HEP-PR-00-71

Report of the Working Group on Photon and Weak Boson Production

E. L. Berger, S. E. Kuhlmann, *et al.*

Proceedings of the Workshop on Physics at Run II at the Fermilab Tevatron:

QCD and Weak Boson Physics, Batavia, IL, November 4-6, 1999.

ANL-HEP-PR-00-60

S- and *U*-Duality Constraints on *IIB* *S*-Matrices

G. Chalmers

Nuclear Physics B

ANL-HEP-PR-00-005

Search for New Particles Decaying to $t\bar{t}$ in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman,

J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF*

Collaboration

Physical Review Letters, accepted

ANL-HEP-PR-00-70

Search for Second and Third Generation Leptoquarks Including Production via

Technicolor Interactions in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman,

J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF*

Collaboration

Physical Review Letters, accepted

ANL-HEP-PR-00-75

Search for the Charged Higgs Boson in the Decays of Top Quark Pairs in the et and $m\bar{t}$

Channels at $\sqrt{s} = 1.8$ TeV

R. E. Blair, K. L. Byrum, E. Kovacs, S. E. Kuhlmann, T. LeCompte, L. Nodulman,

J. Proudfoot, R. Thurman-Keup, R. G. Wagner, A. B. Wicklund, and the *CDF*

Collaboration

Physical Review D, accepted

ANL-HEP-PR-00-52

Soft-Gluon Angular Screening in Heavy-Quark Fragmentation

S.V. Chekanov

Physics Letters B, accepted

ANL-HEP-PR-00-46

Supersymmetry Breaking, Fermion Masses and a Small Extra Dimension

D. E. Kaplan and T.M.P. Tait

JHEP

ANL-HEP-PR-00-43

Technical Compact Essay Encyclopaedic Entry Contribution

C. Zachos

Concise Encyclopedia on Supersymmetry and Noncommutative Structures in Mathematics and Physics, edited by J. Bagger, S. Duplij, and W. Siegel (Kluwer Academic Publishers, Dordrecht), in press.

ANL-HEP-PR-00-67

The Past and Future of S-Matrix Theory

A.R. White

Scattering, edited by E. R. Pike and P. Sabatier (Academic Press), accepted.

ANL-HEP-PR-00-11

The Radiation Environment in and near High Gradient RF Cavities

J. Norem

Nuclear Instruments and Methods in Physics Research

ANL-HEP-PR-00-89

The Universality of the Finite Temperature Transition in Two Flavor Quantum Chromodynamics

J. B. Kogut and D. K. Sinclair

Physical Review Letters

ANL-HEP-PR-00-49

IV.C. PAPERS OR ABSTRACTS SUBMITTED TO CONFERENCES

A Comparison of Spin Observable Predictions for RHIC

G. P. Ramsey

Circum-Pan-Pacific RIKEN Symposium on High Energy Spin Physics (Pacific Spin 99), Wako, Japan, November 3-6, 1999.

ANL-HEP-CP-00-04

A High-Charge High-Brightness L-Band Photocathode RF Gun

M. E. Conde, W. Gai, R. Konecny, J. G. Power, P. Schoessow, and X. Sun

Proceedings of the ICFA Workshop, "The Physics of High Brightness Beams," Los Angeles, CA, Nov. 9-11, 1999, edited by J. Rosenzweig and L. Serafini (World Scientific, Los Angeles, 2000), accepted.

ANL-HEP-CP-00-07

Bose-Einstein Correlations in $e^+e^- \rightarrow W^+W^-$ at a Linear Collider

S. V. Chekanov

Proceedings of the Workshop on Physics Studies for a Future Linear Collider, QCD Working Group 2000, Hamburg, Germany.

ANL-HEP-CP-00-03

Commodity Multi-Processor Systems in the ATLAS Level-2 Trigger

R. E. Blair, J. W. Dawson, and J. Schlereth

Proceedings of 2000 IEEE Nuclear Science Symposium: 2000 Nuclear Science Symposium and Medical Imaging Conference, Lyon, France, October 15-20, 2000.

ANL-HEP-CP-00-51

Constraints on the Gluon Density from Lepton Pair Production

E. L. Berger and M. Klasen

Proceedings of the Fermilab Workshop on Physics at Run II, QCD and Weak Boson Physics, Batavia, IL, November 4-6, 1999.

ANL-HEP-CP-00-02

Experimental Demonstration of Dielectric Structure Based Two Beam Acceleration

W. Gai, M. E. Conde, R. Konecny, J. G. Power, P. Schoessow, X. Sun, and P. Zou

Proceedings of the 9th Advanced Accelerator Concepts Workshop (AAC), Santa Fe, NM, June 10-16, 2000.

ANL-HEP-CP-00-125

Experimental Measurements of Wakefields in a Multimode, Dielectric Structure Driven by a Train of Electron Bunches

J. G. Power, M. E. Conde, W. Gai, A. Kanareykin, R. Konecny, and P. Schoessow

Proceedings of the 9th Advanced Accelerator Concepts Workshop (AAC), Santa Fe, NM, June 10-16, 2000.

ANL-HEP-CP-00-103

Fragmentation in the Nonperturbative Regime

G. T. Bodwin and B. W. Harris

Workshop on B Physics at the Tevatron Run II and Beyond, Batavia, IL, February 24-26, 2000.

ANL-HEP-CP-00-64

Initial Results of the New High Intensity Electron Gun at the Argonne Wakefield Accelerator

M. E. Conde, W. Gai, R. Konecny, J. G. Power, P. Schoessow, and X. Sun

Proceedings of the XX International Linac Conference (LINAC 2000), Monterey, CA, August 21-25, 2000.

ANL-HEP-CP-00-91

Lepton Pair Production at the LHC and the Gluon Density in the Proton

E. L. Berger and M. Klasen

Workshop on Standard Model Physics (and more) at the LHC (Final Plenary Meeting), Geneva, Switzerland, October 14-15, 1999.

ANL-HEP-CP-00-09

Longitudinal Spin Dependence of Massive Lepton Pair Production

E. L. Berger

Circum-Pan-Pacific RIKEN Symposium on High Energy Spin Physics,
Wako, Japan, November 3-6, 1999.

ANL-HEP-CP-00-01

Predictions for Associated Production of Gauginos and Gluinos at NLO in SUSY-QCD

E. L. Berger, M. Klasen, and T. Tait

XXXV Rencontres de Moriond, Les Arcs, France, March 18-25, 2000.

ANL-HEP-CP-00-57

Report of SUGRA Working Group for Run II of the Tevatron

C.E.M. Wagner, E. L. Berger, B. Harris, M. Klasen, Z. Sullivan, T. Tait, *et al.*

Workshop on the Physics of Run II -- Supersymmetry/Higgs, Batavia, IL,
November 19-21, 1998.

ANL-HEP-CP-99-101

Tevatron Direct Photon Results

S. Kuhlmann

Proceedings of the 7th International Workshop on Deep Inelastic Scattering and
QCD, Zeuthen, Germany, April 19-23, 1999.

ANL-HEP-CP-99-96

The Measurement of the Mass of the W Boson from the Tevatron

R. Thurman-Keup

Proceedings of the 2nd Latin American Symposium on High Energy Physics, San
Juan, Puerto Rico, April 8-11, 1998.

ANL-HEP-CP-99-87

Top Quark Physics

E. L. Berger, Z. Sullivan, T.M.P. Tait, *et al.*

Workshop on Standard Model Physics (and more) at the LHC, Geneva, Switzerland,
October 14-15, 1999.

ANL-HEP-CP-00-006

Top Spin and Experimental Tests

E. L. Berger and T. Tait

Thinkshop on Top-Quark Physics for the Tevatron Run II, Batavia, IL,
October 16-18, 1999.

ANL-HEP-CP-00-14

Transformer Ratio Enhancement Using a Ramped Bunch Train in a Collinear Wakefield Accelerator

J. G. Power, W. Gai, and A. Kanareykin

Proceedings of the 9th Advanced Accelerator Concepts Workshop (AAC),
Santa Fe, NM, June 10-16, 2000.

ANL-HEP-CP-00-102

What is Coherent in Neutrino Oscillations. The Analog with a Two-Slit Experiment

H. J. Lipkin

Carolina Symposium on Neutrino Physics, Columbia, SC, March 10-12, 1999.

ANL-HEP-CP-00-47

V.D. TECHNICAL REPORTS AND NOTES

CDF Notes:

CDF-5214

Comparison of underlying event energy in Herwig and CDF data

A. Bhatti, J. Huston, E. Kovacs, and V. Tano

January 14, 2000

CDF-5219

Prompt Photon Trigger Efficiencies

D. Partos and S. Kuhlmann

January 21, 2000

CDF-5238

Charged Particle Energy Depositions in the Central Electromagnetic Calorimeter

S. Kuhlmann

February 17, 2000

CDF-5283

Defining PAD Format and High Level Objects: Some Thoughts from the B Group

C. Blocker, J. Boudreau, J. Lewis, M. Paulini, S. Tkacek, and B. Wicklund

April 11, 2000

CDF-5332

Run II predictions for $B_s \rightarrow J/\psi + \eta'$

A. B. Wicklund and W. H. Bell

June 2, 2000

CDF-5334

The PT Reach for the B Cross-Section Via $B \rightarrow D0 + e + X$ in Run 2

K. Byrum

June 6, 2000

CDF-5342

Jet Energy Resolution Studies in RunIb Di-jet Sample Using Calorimeter, Tracking and SM Information

A. Bocci, S. Kuhlmann, S. Lami, and G. Latino
June 15, 2000

CDF-5345

Final Tests for the SMD/SQUID Qualification Before Production

K. Byrum, M. Convery, G. Drake, M. Lindgren, R. Keup, S. Kuhlmann, J. Proudfoot, and J. Wu
June 21, 2000

CDF-5346

Tevatron Photon Measurements

R. E. Blair, for the *CDF Collaboration the D0 Collaboration*
June 21, 2000

Mucool Notes:

Mucool Note #85

Muon Diagnostic Issues for the Neutrino Source

J. Norem
February 2000

NuMI Notes:

NuMI-L-626

Conceptual Design of the Clock System for the MINOS Near Detector,
Version 1.3

J. Dawson, G. Drake, and C. Nelson
May 2000

NuMI-L-627

Conceptual Design of the VME Interface for the MINOS Near Detector,
Version 2.3

J. Dawson, G. Drake, S. Madani, C. Nelson, T. Nicholls, and G. Pearce
May 2000

NuMI-L-628

Overview of the Front End Electronics for the Near Detector, Version 1.35

G. Drake, J. Dawson, and C. Nelson
November 1999 (*Not previously reported.*)

NuMI-L-633

Far Detector Installation Procedures, WBS 2.4

D. Ayres and W. Miller

May 2000

NuMI-L-634

Far Detector Checkout and Commissioning: Facilities and Procedures,
WBS 2.4

D. Ayres and W. Miller

May 2000

NuMI-L-635

Soudan Minecrew Hiring Plan, WBS 2.4 and 3.4

D. Ayres and W. Miller

May 2000

NuMI-L-653

The Case for Using Cesium-137 on the Module Mapper Instead of Co-60

L. Mualem

June 2000

NuMI-L-657

Summary of the Electronics/Light Injection System Session at Ely

J. Thron

June 2000

PDK Notes:

PDK-730

The Observation of a Shadow of the Moon in the Underground Muon Flux in
the Soudan 2 Detector

D. S. Ayres, T. H. Fields, M. C. Goodman, T. Joffe-Minor, W. Leeson, L. E. Price,
J. L. Thron, and *the Soudan 2 Collaboration*

Phys. Rev. **D61**: 092002 (2000)

PDK-742

Recent Atmospheric Neutrino Results from Soudan 2

T. Kafka (*for the Soudan 2 Collaboration*)

Nucl. Phys. Proc. Supp. **87**: 186 (2000)

PDK-743

Search for Nucleon Decay into Lepton + K^0 Final States Using Soudan 2

D. S. Ayres, T. H. Fields, M. C. Goodman, T. Joffe-Minor, W. Leeson, L. E. Price,
J. L. Thron, and *the Soudan 2 Collaboration*

Phys. Rev. **D61**: 072004 (2000)

PDK-752

New Results on Atmospheric Neutrinos from Soudan 2

W. A. Mann (*for the Soudan 2 Collaboration*)

PDK-753

Three Flavor n Oscillations with Two Δm^2 Mixing

K. Lamba

Wakefield Notes:

WF-189

Dispersion Relation and Quality Factor of TM_{01m} Modes in Standing Wave Dielectric Structures (*Not previously reported.*)

X. Sun

November 4, 1999

WF-190

Construction and Bench Testing of a Prototype 11.4 GHz Externally Powered Dielectric Loaded Traveling-Wave Accelerating Structure

P. Zou, X. Sun, R. Konecny, M. Conde, and W. Gai

January 6, 2000

WF-191

Vacuum System Testing for X-band Dielectric-Loaded Accelerator Structure

X. Sun, M. Conde, P. Zou, and W. Gai

January 12, 2000

WF-192

Roadmap to Attain 100 MV/m Gradients and 100 MeV Total Energy Gain in Wakefield Acceleration Using the Current AWA Facility

W. Gai and P. Schoessow

January 12, 2000

WF-193

Measurement of Q for X-Band Dielectric Loaded Standing-Wave Accelerating Structures

P. Zou, X. Sun, W. Gai, and T. Wong

February 15, 2000

WF-194

Design of an RF Power Extraction Device for the CLIC Test Facility

W. Gai and P. Schoessow

March 7, 2000

WF-195

Effect of Temperature and Air in RF Cavities

M. E. Conde

January 21, 2000

WF-196

Longitudinal and Transverse Wakefields in a Thin Dielectric Disk Structure

W. Gai, X. Sun , and P. Zou

April 12, 2000

WF-197

Estimate of the Wakefield Generated with the Beam from the New AWA Gun

W. Gai

April 17, 2000

WF-198

A Modified Laser Multi-Splitter for Generation of a Ramped Pulse Train

J. G. Power

June 2000

WF-199

A High Resolution Wakefield Measurement System for the ETF

W. Gai and P. Schoessow

June 23, 2000

V. COLLOQUIA AND CONFERENCE TALKS

David Ayres

Status of the MINOS Experiment

HEP Division Seminar, Argonne, IL, March 29, 2000.

Edmond L. Berger

Associated Production of a Gaugino and a Gluino at Hadron Colliders in Next-to-Leading Order QCD

CTEQ Meeting, Argonne, IL, March 4, 2000.

Longitudinal Spin Dependence of Lepton-Pair Production in Hadron Collisions

RIKEN-BNL Workshop on Predictions for RHIC Spin Physics, Upton, NY, March 15, 2000.

Predictions for Associated Production of a Gaugino and a Gluino at Hadron in SUSY-QCD at Next-to-Leading Order

8th International Conference on Supersymmetries in Physics (SUSY 2K), Geneva, Switzerland, June 25 – July 1, 2000.

Geoffrey T. Bodwin

Factorization of the Heavy-Quarkonium Production Cross Section

Fermilab B-Physics Run II Workshop: Working Group on Production, Fragmentation, and Spectroscopy, February 24, 2000.

Gordon Chalmers

Dual Expansions of Super Yang-Mills Theory Via String Theory and S -Duality

FNAL, Batavia, IL, June 1, 2000.

Dual Expansions in Supersymmetric Gauge Theories Via String Theory and S -Duality

HEP Division Theoretical Physics Seminar, Argonne, IL, May 22, 2000.

Constraints of S - and U -Duality on IIB S -Matrices and Correlators Through the AdS/CFT Correspondence

Universitaet fuer Theoretische Physik, Hannover, Germany, April 11-23, 2000.

Constraints of S - and U -Duality on IIB S -Matrices and Correlators Through the AdS/CFT Correspondence

University of Maryland, Department of Physics, College Park, March 9, 2000.

Constraints of S - and U -Duality on Type IIB S -Matrices
University of Chicago, Department of Physics, IL, March 1, 2000.

Constraints of S - and U -Duality on Type IIB S -Matrices
SUNY, Stony Brook, Department of Physics, NY, February 25, 2000.

Constraints of S - and U -Duality on Type IIB S -Matrices
MIT, Department of Physics, Cambridge, MA, February 29, 2000.

Manoel Conde

Summary Report: Electron Beam-Driven Plasma and Structure Based Acceleration Concepts
Advanced Accelerator Concepts Workshop, Santa Fe, NM, June 2000.

Wei Gai

Dielectric Based Accelerator Concepts: Theory and Experiments
Invited talk at Los Alamos National Laboratory, Los Alamos, NM, May 3, 2000.

Maury Goodman

Long-Baseline Neutrino Experiments
ANL, Physics Division, Argonne, IL, January 21, 2000.

Results from Soudan 2
Invited talk at NNNOO Workshop, Irvine, CA, February 2000.

Brian Harris

PDF⁺⁺ Parton Distribution Function Class Library
CTEQ Meeting, Argonne, IL, March 3, 2000.

David Kaplan

Gaugino Mediated Supersymmetry Breaking
8th International Conference on Supersymmetries in Physics (SUSY 2K), Geneva,
Switzerland, June 29, 2000.

Supersymmetry Breaking Through Extra Dimensions
PHENO 2000 Symposium: Phenomenology for the Nu Century, Madison, WI,
April 17-19, 2000.

Gaugino Mediated Supersymmetry Breaking
University of Chicago, Theoretical Physics Seminar, IL, February 2, 2000.

Harry J. Lipkin

Neutrino Oscillations as Two-Slit Experiments in Momentum Space
HEP Division Lunchtime Seminar, Argonne, IL, March 7, 2000.

James Norem

Muon Cooling Concepts
Muon Storage Ring for a Neutrino Factory International Workshop (NuFact '00)
Monterey, CA, May 2000.

John G. Power

Experimental Measurements of Wakefields in a Multimode, Dielectric Structure Driven by a Train of Electron Bunches
9th Advanced Accelerator Concepts Workshop, Santa Fe, NM, June 2000.

Transformer Ratio Enhancement Using a Ramped Bunch Train in a Collinear Wakefield Accelerator
9th Advanced Accelerator Concepts Workshop, Santa Fe, NM, June 2000.

Jose Repond

Collider Detectors at HERA/DESY
2nd RHIC Workshop, Yale, New Haven, CT, April 2000.

High P_T Jet Photoproduction at HERA
8th International Workshop on Deep Inelastic Scattering and QCD, Liverpool, Great Britain, April 2000.

Zack Sullivan

New Probes for Top Squarks and R-Parity Violation of Hadron Colliders
PHENO 2000 Symposium: Phenomenology for the Nu Century, Madison, WI, April 17-19, 2000.

Timothy Tait

A Supersymmetric Model of Flavor in Extra Dimensions

PHENO 2000 Symposium: Phenomenology for the Nu Century, Madison, WI,
April 17-19, 2000.

Jack Uretsky

Interferometry

HEP Division Lunchtime Seminar, Argonne, IL, May 16, 2000.

Carlos Wagner

Electroweak Baryogenesis in the MSSM

HEP Division Seminar, Argonne, IL, May 24, 2000.

Recent Theoretical Developments in the Higgs Sector of the MSSM

University of Illinois, Champaign-Urbana, April 10, 2000.

The MSSM Higgs Boson Sector with Explicit CP Violation

XXV Recontres de Moriond QCD and High Energy Hadronic Interactions,
Les Arcs, Savoie, France, March 19-24, 2000.

Phenomenological Aspects of Low Energy SUSY

EFI Mini-Symposium, Chicago, IL, February 25, 2000.

Recent Theoretical Developments in the Higgs Sector of the MSSM

2000 Aspen Winter Conference on Particle Physics, “Vistas on XXIst Century
Particle Physics,” Aspen, CO, January 16-22, 2000.

Alan R. White

The Triangle Anomaly and Reggeon Field Theory in QCD

International Symposium on Evolution Equations and Large Order Estimates in QCD,
held in honor of the 60th birthday of Lev Lipatov, St. Petersburg, Russia, April 30-
May 4, 2000.

What I’d Like to Tell Volodya Gribov About the Anomaly in Regge Limits

Gribov-70, Paris, France, March 27-29, 2000.

QCD in the Regge Limit and the Triangle Anomaly

HEP Division Theoretical Physics Seminar, Argonne, IL, March 20, 2000.

VI. HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES

David S. Ayres

Deputy Spokesperson, the MINOS Collaboration.

Edmond L. Berger

Adjunct Professor of Physics, Michigan State University, East Lansing, MI, 1997-present.

Member, CTEQ Collaboration.

Member, High Energy and Nuclear Physics Advisory Committee, Brookhaven National Laboratory, Upton, NY, 1995-2001.

Scientific Program Organizing Committee, XXXVth Rencontres de Moriond, QCD and High Energy Hadronic Interactions, France, March 2000.

Consultant, Department of Energy Review of the High Energy Physics Program at the Stanford Linear Accelerator Center, Menlo Park, CA, April 4-6, 2000.

Organizing Committee, Theory Institute on SUSY & Higgs Physics 2000, Argonne, IL, April 25 – May 12, 2000.

Organizing Committee, 7th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2000), Quebec, Canada, May 22-28, 2000.

Scientific Program Organizing Committee, Fourth Rencontres du Vietnam, Physics at Extreme Energies, Hanoi, July 2000.

Scientific Advisory Committee, Frontiers in Contemporary Physics-II, Vanderbilt University, Nashville, TN, March 5-10, 2001.

Scientific Program Organizing Committee, XXXVIth Rencontres de Moriond, QCD and High Energy Hadronic Interactions, France, March 2001.

Organizing Committee, 8th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2003), New York, May 2003.

Geoffrey Bodwin

Member, Working Group on B Physics, Tevatron Run II Workshop, Batavia, IL, September 1999-present.

Gordon Chalmers

Organizing Committee, Theory Institute on SUSY & Higgs Physics 2000, Argonne, IL,
April 25 – May 12, 2000.

Wei Gai

Member, Scientific and Organizing Committee, Advanced Acceleration Concepts
Workshop 2000.

Maury C. Goodman

Member, Particle Data Group.

Co-Chairman, MINOS Working Group on Theseus.

Member, International Advisory Committee for Neutrino 2000.

Brian Harris

Organizing Committee, Theory Institute on SUSY & Higgs Physics 2000, Argonne, IL,
April 25 – May 12, 2000.

David Kaplan

Organizing Committee, Theory Institute on SUSY & Higgs Physics 2000, Argonne, IL,
April 25 – May 12, 2000.

Edward N. May

Member, ESnet Steering Committee.

Lawrence J. Nodulman

Member, Fermilab Users Organization Executive Committee.

James Norem

Member, Muon Collider Group Technical Committee.

Lawrence E. Price

Chair, ESnet Steering Committee.

Gordon Ramsey

Member, International Advisory Committee, Circum-Pan-Pacific Workshops on High Energy Spin Physics, 1996-present.

Member, SPIN Collaboration.

Paul Schoessow

Webmaster, the APS/Division of Beam Physics.

Hal Spinka

Co-Spokesperson, the Brookhaven experiment E953 (Crystal Ball).

Zack Sullivan

Organizing Committee, Theory Institute on SUSY & Higgs Physics 2000, Argonne, IL, April 25 – May 12, 2000.

Tim Tait

Organizing Committee, Theory Institute on SUSY & Higgs Physics 2000, Argonne, IL, April 25 – May 12, 2000.

Carlos Wagner

Organizing Committee, Theory Institute on SUSY & Higgs Physics 2000, Argonne, IL, April 25 – May 12, 2000.

Cosmas Zachos

Member, Scientific Committee for the NATO Advanced Research Workshop UIC 2000, *Integrable Hierarchies and Modern Physical Theories*, Chicago, IL, July 22-26, 2000.

VII. HEP DIVISION RESEARCH PERSONNEL

Administration

L. Price

D. Hill

Accelerator Physicists

M. Conde

W. Gai

J. Norem

J. Power

P. Schoessow

Experimental Physicists

D. Ayres

R. Blair

K. Byrum

S. Chekanov

M. Derrick

T. Fields

M. Goodman

D. Krakauer

S. Kuhlmann

T. LeCompte

T. Joffe-Minor

S. Magill

E. May

B. Musgrave

L. Nodulman

A. Pellegrino

E. Peterson

J. Proudfoot

J. Repond

H. Spinka

R. Stanek

R. Talaga

J. Thron

R. Thurman-Keup

D. Underwood

R. Wagner

A. Wicklund

A. Yokosawa

R. Yoshida

Theoretical Physicists

E. Berger

G. Bodwin

G. Chalmers

B. Harris

D. Kaplan

D. Sinclair

Z. Sullivan

T. Tait

C. Wagner

A. White

C. Zachos

Engineers, Computer Scientists, and Applied Scientists

J. Dawson

G. Drake

J. Grudzinski

V. Guarino

W. Haberichter

N. Hill

E. Kovacs

J. Schlereth

Technical Support Staff

I. Ambats
S. Anderson
A. Caird
G. Cox
T. Cundiff
F. Franchini
D. Jankowski
T. Kasprzyk
L. Kocenko

R. Konecny
Z. Matijas
T. Nephew
L. Reed
R. Rezmer
J. Rice
F. Skrzecz
K. Wood

Laboratory Graduate Participants

J. Breitweg
W. Bell
R. Green

S. Wolf
P. Zou

Visiting Scientists

E. Kovacs (Theory)
H. Lipkin (Theory)
G. Ramsey (Theory)

Xiang Sun (AWA)
J. Uretsky (Theory)
T. Wong (AWA)